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SHIRAKI, Tokuichi:

Simuliidae of the Japanese Empire

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SIMULIIDAE OF THE JAPANESE EMPIRE

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Tokuichi SHIRAKI

(Accepted for publication, February 21, 1935.)

In the year, 1918, I published a monograph of Tabanidae found in the Japanese Empire under the title of "Blood-Sucking Insects of Formosa." The present paper, part two of that study, is a systematic study of the Simuliidae.

During the past fifteen years in several entomological investigations I have collected many baffalo-gnats, mainly in Japan and Formosa, and during the period 1926 to 1928 had very good opportunities to compare them with all the types of this family especially those deposited in the British Museum, the Zoologisches Mureum in Berlin, and the Muséum National d'Histoire Naturelle in Paris. Recently I had a time to study the collections in the Entomological Museum of the Hokkaido Imperial University and of the Government Research Institute of Formosa.

All these studies are incorporated in the present work, which gives a general idea of the Simuliid-fauna of our lands, and includes descriptions of twenty four species of this small family, belonging to six genera, namely *Prosimulium*, *Helodon*, *Stilboplax*, *Eusimulium*, *Simulium* and *Odagmia*. Nearly all of these are new species, excepting, perhaps, only one species, *venustum* Say, which is found in Sachalien.

[Mem. of the Fac. of Sci. and Agr., Taihoku Imp. Univ., Formosa, Japan, Vol. XVI, No. 1, June, 1935.]

I am pleased to have this opportunity of expressing my sincere thanks to those who with unfailing courtesy, have helped me for several years by presenting specimens. My acknowledgements in this direction are due particularly to Prof. Dr. S. MATSUMURA, Prof. Dr. S. ISSIKI and Mr. S. KATO. My cordial thanks are also due to Mr. B. SAKUMA whose beautiful and accurate drawings reveal many details which are difficult to express in words.

Finally I must render grateful thanks to Dr. F. W. EDWARDS, Prof. Dr. G. ENDERLEIN and Prof. E. SÉGUY, for giving me free access to their splended collections.

Key to the genera found in the Japanese Empire

1. Radial vein setose on its entire length.
    2. Radial sector forked.
        3. Claws of hind legs of female simple.................... **Prosimulium,** ROUBAUD (Typ. *hirtipes,* FRIES)
        33. Claws of hind legs of female with basal or subbasal tooth.. **Helodon,** ENDERLEIN (Typ. *ferrugineus,* WAHLGR.)
    22. Radial sector simple.
        3. Claws of hind legs of female simple.................... **Stilboplax,** ENDERLEIN (Typ. *speculiventris,* FNDERLEIN)
        33. Claws of hind legs of female with tooth.............. **Eusimulium,** ROUBAUD (Typ. *aureum,* FRIES)
11. Radial vein bare between the stem vein and base of radial sector; radial sector simple.
    2. Claws of hind legs of female simple.............................. **Simulium,** LATREILLE (Typ. *reptans,* LINNAEUS)
    22. Claws of hind legs of female with subbasal tooth......... **Odagmia,** ENDERLEIN (Typ. *ornata,* MEIGEN)

Genus **PROSIMULIUM,** ROUBAUD

Compt. Rend. Acad. Sci. Paris, vol. 143, p. 519 (1906).

Prosimulium, MALLOCH (pt), U. S. Dept. Agr., Bur. Ent., Tech. Ser., No. 26, p. 15 (1914).

Prosimulium, ENDERLEIN (pt), Deutsch. Tierarzt. Woch., Hannover, No. 16, p. 199 (1921); Zool. Anz., LIII, p. 44 (1921).

Genotype: *Simulium hirtipes,* FRIES.

Key to the our species

1. Hind legs yellowish..*yezoense*, sp. nov.
11. Hind legs blackish..*kiotoense*, sp. nov.

1. **Prosimulium yezoense**, sp. nov.

Pl. I, fig. 2; Pl. V, figs. 1-9.

Simulium rufipes, ROUBAUD (nec MEIGEN), Bull. Mus. S. Hist. Nat., XII, p. 26 (1906)

This species has no silvery grey patch on legs, and has the distinct basal cell of wing. The present species agrees with MEIGEN's description of *rufipes*, but it is easily distinguished from european *rufipes* by its comparatively shorter hind metatarsus. It is also very closely allied to *gallii*, EDWARDS (Ann. Mag. Nat. Hist., 1921 (Jan), p. 141), but differs in the reddish shoulders, in the distinct yellow basal half of wing, in the yellow femora, in the narrow hind metatarsus, etc.

♀. Head greyish black, narrower than the thorax. Frons somewhat triangular, narrowed towards the lower end, with rather straight sides, about as long as its broadest part, covered with numerous yellowish pubescence which is not quite depressed. Face oval with a somewhat pointed upper margin and a somewhat straight lower margin, castaneous black, covered with yellowish pubescence which is shorter and sparser than that on the frons. Back of the head covered with a dense conspicuous yellowish white pubescence which is intermixed with a few black erect pubescence near the eye-margin, where there is no distinct bare postocular rim. Proboscis rather long and stout, longer than wide; labrum yellowish castaneous, about twice as long as wide; paraglossa somewhat paler than the labrum, furnished with a few yellowish white pubescence. Palpi dark brown, with two apical joints paler, obscured by a grey dust, and furnished with yellowish white hairs, 5-jointed; the third joint largest, about ⅓ as wide as long, covered with numerous hairs intermixed with a few blackish rather erect pubescence at the apical portion, the sensory vesicle rather small and occupied on one side of the basal half; the 4th joint about $\frac{2}{3}$ times as long as or about twice as wide as the 3rd, dilated toward the apex, the surface transversely striolated and covered with yellowish white hairs which are somewhat fewer than those on the 3rd; the apical joint shorter than the 3rd and conspicuously longer than the 4th, but narrower than the latter, narrowed about the middle and apex the latter being rounded, the greatest width is at the basal portion, the surface is furnished with numerous transverse stripes and a few blackish hairs. Antennae dark brown, obscured by a greyish dust and covered with a dense yellowish very short pubescence which becomes longer and blackish on the outer side; the first joint small, furnished with a few conspicuous yellowish pubescence on the apical margin; the second joint longer than the first annulation of styli but narrower, pale on apical half or more; the apical annulation of styli narrowest but longer than the basal annulation, furnished with four blackish curved spine-like tiny hairs. Eyes bare from pubescence, with the facets all practically equal.

Thorax black, obscured by a greyish dust and covered with a dense depressed golden yellow pubescence, without any stripes; shoulders and lateral margins of mesonotum conspicuously castaneous, furnished with a few yellow pubescence; pronotum castaneous, covered with a few very short yellowish pubescence; pleurae castaneous, becoming paler just below the wing-base, a few pubescence on the prothoracic episternum, postparapterum and others, but quite bare on the membranous area and metathoracic epimera. Scutellum brown, covered with many golden yellow hairs; mesothoracic postnotum blackish, covered with a greyish dust.

Abdomen blackish, paler on the basal tergites and the ventre, covered with a greyish dust and a yellowish white pubesence which becomes somewhat longer towards the basal portion especially on the lateral margin; the basal scale brown, furnished with a fan-shaped row of yellow hairs. Genital part paler than the anal segment; the subgenital plate palest, triangular with the apex round, longer than wide, furnished with a few yellowish pubescence at the basal area; the lateral plate rather small, flat-triangular, darker than the subgenital plate; cerci large, reaching beyond the apex of the subgenital plate, furnished with a few pubescence at the apical area especially on the lower margin.

Legs yellowish, with the black tarsi and the somewhat dark coxae. Fore legs shorter and narrower than the hind legs; femora slightly longer and conspicuously broader than the tibiae, covered with a yellowish white pubescence which is intermixed with a very few dark erect hairs on the basal upper margin and with a very few paler erect pubescence; tibiae with an apical dorsal blackish portion where there are some blackish very short bristle-like hairs, and where there is a tiny black apical spine, covered with a yellowish pubescence which becomes somewhat longer and erect on the under margin; metatarsi slightly longer than half the tibiae, rather narrow, about as long as the three following tarsal joints together, covered with numerous yellowish pubescence which are intermixed with a few long hairs on the upper margin and with about 20 short black spines on the under margin; 2nd tarsal joint about 1½ times as long as the following one, covered with a yellowish pubescence intermixed with many dark hairs on the upper surface and with some short black spine-like hairs; the 3rd tarsal joint similar to the preceding one but shorter; the 4th about half as long as the 2nd, furnished with pubescence like the preceding one but the spine-like hairs are fewer; the apical tarsal joint narrowest, slightly shorter than the 3rd, the pubescence the same as that on the 4th. Claws slender, with no tooth but moderately tuberculate. Hind legs coloured and pubescent as in the front legs; femora as long as the tibiae; tibiae about as long as the two following ones together, with the two apical spines black and conspicuous. Hind tarsi longer and broader than the front tarsi; metatarsi conspicuously longer and broader than the front metatarsi, longer than the 4 following ones together, the spines on the under margin number 16 and are longer than those on the front metatarsi; 2nd tarsal joint narrow, about ⅓ as long as the metatarsi, with no excision; the 3rd shorter and narrower than the front 3rd tarsal joint, with two tiny apical spines on the lower surface; the fourth about as long as the front one; the apical joint about as long as that of the front legs. Claws slender as those of the front legs.

Wings somewhat smoked, with the base yellowish; veins yellowish, excepting of the costa brown; radial vein forked just after the ending of subcostal vein; median vein forked short after the base, the both branches curved below conspicuously; basal cell distinct and well defined. Halteres yellowish.

Length of body: 3.4–3.6 mm. Length of wings: 4.3-4.5 mm.

Described from three females, one of which is collected at Zio-zankei and others at Sapporo, Hokkaido. The two latter specimens have darker colouration and black knees.

2. **Prosimulium kiotoense,** sp. nov.

Pl. I, fig. 1; Pl. VI, figs. 1-9.

Allied to *hirtipes*, FRIES, but easily distinguished by the proportionate length of each the hind tarsal joints, and by the narrow hind tibiae and tarsi, as well as by the very indistinct basal cell of wings.

♀. Head greyish black. Frons somewhat triangular, with straight sides, about as long as its broadest part and about three times as long as its narrowest part, covered with a grey dust and many depressed yellowish white pubescence which are intermixed with a very few black curved hairs on the lateral borders. Face roundish, with the pointed upper angle, covered with a greyish white dust and a depressed yellowish white pubescence which becomes shorter and sparser on the upper border; near the lateral margins there is a row of black hairs, which is rather inconspicuous. Vertex convex, covered with a greyish dust and numerous yellowish white pubescence; occiput densely covered with long yellowish white hairs which become shorter toward the lower portion, near the eye-margin there is a row of a few long stout black hairs and there is no bare postocular rim. Proboscis short and stout, blackish brown, furnished with a short blackish pubescence; labrum reddish yellow. Palpi blackish, obscured by a greyish tomentum, furnished with yellowish hairs and black bristly hairs, 5-jointed; the first joint as long as the second, blackish, furnished with a few long yellowish hairs on the lower outer portion; the second paler than the first, and with two or three blackish bristly hairs near the apex of the lower outer side; the third slightly darker than the 2nd, about three times as long as the 2nd, thickest all and about twice as wide as, the preceding ones, covered with long black bristly hairs which are intermixed with a few yellowish pubescence on the apical border, with the sensory vesicle very large and occupied on the basal two-thirds; the fourth joint slender, slightly dilated toward the apex, about two-thirds as long as the 3rd, the surface irregularly and transversely striolate and covered with many long yellowish hairs which are intermixed with slightly shorter black bristly hairs on the apical portion, at the apex there is an incomplete sensory vesicle; the 5th a little shorter than the preceding one, irregularly constricted especially strongly at a point about two-thirds from the base, much more striolate than on the fourth joint, furnished with sparse yellowish hairs. Antennae black, obscured by a greyish dust and covered with a dense greyish yellow pubescence, and on the upper side there are short blackish hairs; the second joint a little longer than the basal annulation of the style, furnished with longer black somewhat bristly hairs on the upper margin but the tomentum less conspicuous; the apical annulation of style shorter than the basal one but much longer than the preceding ones, the apex with two or three conspicuous hairs. Eyes bare from pubescence, with the facets all practically equal.

Thorax black obscured by a greyish dust and covered with numerous short depressed yellowish hairs, without any stripes; the shoulders not conspicuously convex, somewhat brownish; pleurae greyish, slightly brownish just below the base of wing, bare from pubescence but on the prothoracic episternum there is some yellowish pubescence; scutellum brownish black, covered with a greyish dust and a yellowish pubescence which is a little longer than that on the notum. Mesothoracic postnotum dàrker than the scutellum, covered with a yellowish dust.

Abdomen blackish brown, paler towards the base and the ventre, covered with a greyish dust and a greyish pubescence; the basal scale brown, furnished with a fan-shaped row of pale yellowish hairs. Genital part dark; the subgenital plate with a long yellowish brown process furnished with a few pubescence; the lateral plates large, somewhat quadrate, gradually narrowed towards the ventre, furnished with a few pubesence at the margin especially on the upper margin, cerci compressed laterally, with round tip where there is a few conspicuous pubescence.

Legs yellowish, with the coxae, the both ends of tibiae, and the tarsi brownish. Fore legs shorter and narrower than the hind legs; femora dilated, about twice as wide as tibiae, shorter than tibiae, paler than the remaining ones and slightly brownish at the apex; tibiae about as long as the two first joints of tarsi together, with a conspicuous apical spine; tarsi slender and long; metatarsi not dilated, about as long as the two following joints together, the underside furnished with about 12 short blackish spines and the upper side with some long paired hairs; the second joint of the tarsi very slightly broader than the metatarsi, shorter than the third and fourth joints together, on the under surface there are about 10 short blackish spines and on the upper surface a few long hairs; the third tarsal joint about as broad as the preceding joint, shorter than the two following joints together, with a few minute blackish spines and long hairs respectively on the under and upper surface; the fourth tarsal joint about as long as the fifth but much broader, a few long hairs on the upper side and a few short pubescence on the lower surface; the apical tarsal joint slender, somewhat constricted at the middle, hairy and pubescent; pubescence mostly yellowish but on the blackish portion there are numerous conspicuous black hairs. Hind legs longer and much more pubescent than the front legs; femora a little longer and much broader than the tibiae; tibiae about as long as the two first tarsal joints together, with two apical spines which are about as long as those on the front tibiae; metatarsi longer than the four following tarsal joints together, conspicuously dilated, the under margin with about 14 blackish spines, and the upper surface with numerous long hairs; the second tarsal joint slender, straight and without dorsal excision, about twice as long as the third joint, on the under surface there are many blackish long bristly hairs and on the upper side much longer hairs; the third tarsal joint slightly widened toward the apex, about as long as the apical tarsal joint, a very few blackish minute spines on the under surface and many long hairs on the upper surface; the fourth tarsal joint shortest, on the under surface there is a dense pubescence and on the upper surface a few long hairs; the apical tarsal joint narrowest, no spines but hairy as in the front legs; pubescence as in the front legs, but much longer, denser and paler. Median legs the same as the hind legs, but shorter. Claws not pointed, at the base conspicuously dilated but not produced spine-like.

Wings very slightly smoked, with yellowish brown veins, comparatively large; veins not usual, the radius with a distinct branch which commences before the middle, the medius connected with the radius by a long and strong stalk, the cubital vein forked far beyond the middle of whole length; basal cell not distinct. Halteres pale yellowish brown.

Length of body: 2.5-3.5 mm. Length of wings: 3.5-4.5 mm.

Described from two females from Kioto, collected by the author on the 19th of April, 1914; the type is preserved in the Entomological Museum of the Government Research Institute, Taihoku, Formosa.

Genus **HELODON**, Enderlein

Deut. Tierarz. Woch., Hannover, No. 16, p. 199 (1921).

Genotype: *Simulium ferrugineum*, Wahlberger

Enderlein's *Helodon* differs from *Prosimulium*, Roubaud, only in the toothed hind claws of female and in the rather indistinct prolongation of hind metatarsi of female, as well as in the rather indistinct basal cell of female-wings.

In the Japanese Empire there is only one species described below.

3. **Helodon sapporoensis**, sp. nov.

Pl. II, fig. 2; Pl. VII, figs. 1-7.

♀. Closely allied to *S. hirtipes* FRIES and *kiotoënse*, m., but it is quite different in having the two teeth of claws, both in the form of the subgenital plate and from the latter in the proportional length of each the tarsal joints.

Head distinctly narrower than the thorax. Face large and oval, with nearly straight sides, slightly narrower than one third the width of the head, longer than the width, black, furnished with numerous short depressed yellowish white pubescence. Frons broad, somewhat triangular, narrowed toward the lower end with very slightly curved lateral margins, black, and densely covered with a pubescence which is the same as that on the face. Vertex broad, in the middle somewhat concave, black, covered with depressed yellowish pubescence intermixed with a very few erect black hairs which are very inconspicuous and extend towards the occiput. Postocular portion of back of the head slightly dusted with grey color, and there is no distinct bare rim. Back of the head thickly covered with yellowish pubescence which is longer than that on the occiput. Proboscis thick and short, triangular viewed from the front, and as wide as long; labrum castaneous. Palpi dark brown somewhat obscured by a greyish tomentum, furnished with yellowish hairs and black pubescence, 5-jointed. First joint of palpi as long as the second, brownish, furnished with a few hairs near the apex; the second joint darker than the first, the hairs near the apex more numerous than those of the first; the third slightly darker than the second, about four times as long as and about 1½ times as wide as the 2nd, the hairs on the surface shorter than those of *kiotoense* and fewer, the sensory vesicle rather small; the 4th slender as usual, distinctly shorter than the preceding joint, the surface slightly striolate and covered with a few hairs; the 5th very slightly longer than the 4th and as wide as the latter, the hairs on the surface fewer than on the 4th, conspicuously narrowed before the middle, the striolation distinct. Antennae blackish, obscured by a greyish tomentum, covered with numerous yellowish pubescence, and on the upper surface there are short blackish hairs; the second joint twice as long as the basal joint and about as long as the basal annulation of style; the apical annulation slightly longer than the basal one, moderate conical. Eyes bare from pubescence, with the facets all practically equal.

Thorax blackish, obscured by a greyish dust and covered with numerous short depressed yellowish white pubescence, without any stripes; the shoulders brown, reddish below; pleurae blackish brown, somewhat reddish just below the wing-bases, bare from pubescence but on the prothoracic and mesothoracic episternum a few yellowish ones. Scutellum paler than the scutum; mesothoracic postnotum darker than the scutellum, sparsely covered with a yellowish pubescence.

Abdomen blackish brown, somewhat paler towards the base and the ventral surface, covered with a greyish dust and a yellowish white pubescence which becomes more whitish at the apical portion; the basal scale brown, furnished with a fan-shaped row of yellowish hairs; the genital part dark, the subgenital plate truncate at the apex.

Legs yellowish pubescent and dusted, yellowish brown, with the coxae, the both ends of tibiae and the tarsi darker. Fore legs shorter and narrower than the hind legs; femora dilated, about twice as wide as tibiae and somewhat shorter than the latter, slightly darker towards the apex; tibiae about as long as the two first joints of tarsi together; with a conspicuous apical spine and a few fine hairs; tarsi slender and long; metatarsi conspicuously longer than the two following joints together, with 16 short blackish spines and a very few long fine paired hairs, at the apex there is a distinct spine; 2nd tarsal joint shorter than the 3rd and 4th together, with a few long hairs; the third tarsal joint broader than the 2nd and much longer than the fourth; the 4th shorter than the 5th, but broader; the apical joint with claws which have two short teeth near the base, the first tooth broader and larger than the 2nd one. Hind legs thicker and much more pubescent than the front legs; femora slightly longer than the tibiae, broadened about the middle, about twice as wide as the tibiae which are distinctly blackish at the basal portion and are gradually broadened towards the apex where are two curved spines; tarsi about as long as the front tarsi but conspicuously broader; metatarsi distinctly longer than the remaining ones together, on the under margin there are many black very short bristle-like hairs, on the opposite margin with a few fine long paired hairs and numerous depressed pubescence which becomes longer and darker at the apex; second tarsal joint rather short, longer than $\frac{1}{3}$ the length of metatarsi, on the upper margin there is no excision and are many long hairs, on the under margin there are numerous short black bristly hairs; the third joint half as long as and broader than the 2nd; the 4th conspicuously shorter than the 3rd; the apical tarsal joint longer than the 3rd.

Wings very slightly smoked, with yellowish brown veins which are much the same as *kiotoense*, but basal cell distinct. Halteres pale yellowish brown.

Length of the body: 2.5-3.5 mm. Length of the wings: 4.5-5 mm.

Described from 18 females of which 16 were collected at Sapporo on May and 2 at Nikko in March. Type is preserved in the Entomological Museum of the Government Research Institute, Taihoku, Formosa.

Genus **EUSIMULIUM**, ROUBAUD

Comp. Rend. Acad. Sci. Paris, vol. 143, p. 519 (1906).

Prosimulium, MALLOCH (part), U. S. Dept. Agric., Bur. Ent., Tech. Ser. No. 26, p. 14 (1914).

Prosimulium, ENDERLEIN (part), Deutsch. Tierarz. Woch., Hannover, No. 16, p. 199 (1921); Zool. Anz., LIII, p. 44 (1921).

Nevermannia, ENDERLEIN, Deutsch. Tierarz. Woch., Hannover, No. 16, p. 199 (1921); Zool. Anz., LIII, p. 44 (1921).

Edwardsellum, ENDERLEIN, Deutsch. Tierarz. Woch. Hannover, No. 16, p. 199 (1921); Zool. Anz., LIII, p. 44 (1921).

Genotype: *Simulium aureum*, FRIES.

Key to the species found in our countries

1. Legs yellowish, with blackish portions.
  2. Tooth of claws gradually narrowed toward the pointed tip......*falcoe*, sp.nov.
  22 Tooth of claws more or less constricted before the tip.
    3. Antennae blackish..*taipei*, sp. nov.
    33. Antennae orange-yellow.......................................*geniculare*, sp. nov.
11. Legs dark brown; tooth of claws more or less constricted before the tip; antennae blackish..*bonninense*, sp. nov.

4. Eusimulium falcoe, sp. nov.

Pl. I, fig. 3; Pl. IX, figs. 1-5.

♀. Closely allied to european *aureum*, FRIES, but easily distinguished by the coloration of antennae and posterior legs, as well as by its less hairy and bristled hind metatarsi.

Head blackish. Frons triangular, about as wide as $\frac{2}{3}$ the length, covered with a greyish white dust, and furnished with many rather depressed somewhat long yellowish white pubescence which extend to the vertex. Face roundish, slightly wider than long, with a nearly straight lower margin and a prolonged narrow upper margin which conspicuously projects between the antennal bases and is connected with the lower margin of frons which has a longitudinal sulcus, conspicuously covered with a greyish white tomentum and with numerous yellowish pubescence which are almost always much fewer at the middle and about equal in length to that on frons but sloping below and slightly curved inwards. Back of the head covered with numerous depressed yellowish white pubescence, excepting of a very narrow not well-defined black postocular bare rim, which is intermixed with a few black hairs just behind the vertex; vertex greyish white. Proboscis blackish, conical, with a narrow round apex where it is distinctly yellowish brown, furnished with a few minute blackish pubescence on the base and with a very minute pale yellowish one on apical part; the apical margin furnished with a few black minute serration which is easily seen from side. Palpi rather slender, brownish black, but covered with a greyish dust especially on the upper and outer surfaces; the third joint slender and peculiarly curved at the base, longer and narrower than the remaining ones covered with a very few short pubescence; the second joint narrower than the first but slightly longer, gradually broadened apically and covered with many conspicuous blackish hairs; the basal joint somewhat conical, covered with many long blackish hairs which on the apex are conspicuously long especially two or three. Antennae yellowish, but the two or three first annulations of the third joint slightly brownish, covered with a dense very short depressed whitish pubescence; the two first joints rather bare from pubescence but there are a very few somewhat long yellowish hairs which are conspicuously longer on the basal joint; the apical annulation of the third joint furnished with a few black stout hairs on the tip; the first annulation of third joint longer and broader than the second joint and the top annulation as long as the latter; all annulations of the style rather indistinct. Eyes bare, with the facets all practically equal in size.

Thorax black, very slightly obscured by a greyish dust and densely covered with a yellow depressed pubescence which is especially dense at the side and the fore border; scutellum black but very slightly brownish at the base, almost bare from pubescence; metanotum the same as the scutellum, but slightly obscured by a greyish dust. Pleurae yellowish brown but distinctly darker below, covered with a grey dust, with a very small patch of minute yellow hairs just below the base of wing. Prothorax very small, brownish black, with a few whitish yellow pubescence.

Abdomen velvet-black, covered with a dense yellow pubescence; the bosal scale pale yellowish, furnished with long yellowish hairs at the side and covered with dense curved shorter yellowish hairs on the middle area.

Legs yellowish, with brownish coxae. The front pair pale yellow, with the tarsi black; femora slightly brownish near the tip, a little shorter than the tibiae which are slightly darkened with a brownish tinge on the apical half; tarsi entirely black, the first joint about $\frac{3}{5}$ as long as femora and about as long as the three following joints together; pubescence yellow, intermixed with a few black stout hairs at the outer apex of femora and on the brownish area of tibiae with short depressed blackish ones, the pubescence on the upper side of tarsi longer than that on other side, especially on the three apical joints. The hind pair yellowish, with the apex of femora and tibiae, the apical half of the first joint of tarsi, 2nd to 5th joints of tarsi, and near the base of the tibiae, blackish; the femora a little longer than tibiae which have two distinct black spines at the tip; metatarsi about $\frac{3}{4}$ as long as the tibiae, and nearly twice as long as the following joints together, the second joint of tarsi longer than the following ones, the upper base, just before the definite excision furnished with blackish hairs; pubescence short and yellowish, but intermixed with many blackish hairs on the blackish parts, and on the upper side of the first joint of tarsi there are five long but fine hairs. The middle pair nearly as in the fore legs but the colour of the femora and tibiae as in the hind one. Claws black, with a stout conspicuous tooth projecting from the base, which is broader than the claw proper.

Wings clear; median vein forked just near the base with a very short stalk; cubital vein forked at a point about two-thirds from the base. Halteres fresh yellow.

Length of body: 1.7–1.9 mm. Length of wings: 2.5–2.7 mm.

Described from only two females collected by the author, on the 26th of March, 1920, in Kappansan, about 300 meter high, among the feathers of *Falco tinnunculus japonicus;* type in the Entomological Museum of the Government Research Institute, Taihoku, Formosa.

5. **Eusimulium taipei,** sp. nov.

Pl. I, fig. 6; Pl. VIII, figs. 13-18.

Very near to the preceding species, but easily distinguished by the form of claws, as well as by the coloration of hind legs.

♀. Head blackish. Frons nearly as long as one-third the length of the head and apparently as long as twice the width of the upper margin, the lower margin nearly straight with a distinct triangular deep furrow before the end, on the upper ridge of this sulcus there are two long black bristly hairs, one on the each side; the surface covered with a dense greyish dust and with many sloping bright yellow hairs. Face somewhat quadrate, with a short upper prolongation which is separated by a distinct transverse furrow from frons obscured by a grey dust and covered with many pale bright yellow pubescence intermixed with rather erect but curved black hairs which are mostly longer than the yellow ones. Back of the head covered with numerous yellow pubescence, intermixed with a few black hairs on the upper half especially just behind the vertex, excepting for a narrow not well defined postocular bare rim; vertex greyish black, covered with a dense yellow pubescence which is a little longer than that on the frons. Proboscis brown, with the base and apex yellowish, covered with numerous black hairs. Palpi blackish with the brownish apical joint, obscured by a grey dust excepting the under surface of the 3rd joint and the tip of the 4th joint, the former being quite black and broadly sulcate and the latter yellowish; pubesoence mostly yellowish but on the apical joint there are many black ones intermixed and on the inner margin of the black bare rim on under surface of the 3rd joint there is a row of black bristly hairs; the 3rd joint apparently longer and broader than the 4th, with a large sensory vesicle which is about half as long as the joint. Antennae dark brown, with the scape yellowish obscured by a grey dust and tomentum; the first flagellar joint broader and longer than the scape which is about as long as the apical flagellar joint and is furnished with a few hairs at the externo-apical margin; the apical flagellar joint with two long but minute hairs on the tip. Eyes bare, with the facets all practically equalm in size, the facets slightly larger than those in *Eusimulium jalcoe.*

Thorax reddish brown with three narrow dark brown longitudinal stripes of which the middle one is narrowest and the lateral pair is about twice as wide as the middle one, entirely obscured by a dense depressed golden yellow pubescence; the middle stripe straight from the anterior margin to betore the posterior margin; the lateral stripes slightly divergent hindwards, and nearly reaching to the posterior margin, they being thickened considerably near the shoulders; the shoulders rather broadly yellowish brown. Pleurae brown, moderately obscured by a greyish dust, bare from pubescence but on a point just before the base of the halteres there is an inconspicuous patch of a few soft yellowish hairs; prothorax yellowish brown, coverd with a few pale yellow pubescence. Scutellum reddish brown, covered with a few golden yellow pubescence; metanotum slightly darker than the scutellum, with a similar pubescence.

Abdomen blackish, covered with a reddish brown or yellow-tipped black pubescence, intermixed with yellowish hairs at the sides; the basal scale yellowish brown, furnished with the usual fan-shaped row of yellowish hairs towards each side; the under surface reddish brown, with numerous short yellowish hairs.

Legs yellowish brown, with the tarsi blackish excepting the mostly part of hind metatarsi. Fore legs much darker; femora dark brown along the upper margin especially at the tip, covered with a dense depressed golden yellow pubescence which is intermixed with numerous black hairs on the outer side and apical part, near the middle of the upper margin there are two long black hairs; tibiae slender and longer than the femora, brown, covered with black hairs of which those on the upper margin are much longer than on the lower margin and which are intermixed with yellow pubescence especially on the inner and outer sides, a very few considerably long black hairs on the upper margin. The lower apex with a black spine; tarsi very long and slender, blackish, the first joint a little shorter than the tibiae and a little longer than the three following joints together, covered with a black pubescence which is much longer on the upper margin than that on the remaining part, and on a point near the apex of each of the 1st, 2nd and third joints there are two conspicuously long black hairs which are longer than the third joint, the apical joint furnished with three or four black bristly hairs on the upper margin, the similar but fine ones on the 4th joint. Middle legs paler than the fore legs, but the femora have a more distinct blackish apex; the tibiae longer than the femora, brownish, with the apical one-third and an inconspicuous ring before the base darker; tarsi more slender and a little shorter than in the fore legs, dark brown, the proportionate length of each joints nearly the same as that of the fore legs, with a black spine at the lower apex; pubescence almost similar to that on the fore legs. Hind legs distinctly paler than others, with the femora, tibiae and metatarsi yellowish; the femora with the apical one-fourth blackish, a little shorter than the tibiae, on the inner side shining, quite bare from pubescence, slightly furrowed, and minutely striate transversely; tibiae with the apical one-third brown but not well-defined, gradually widened towards the apex, much broader than those in the middle legs, the upper margin slightly curved below about the middle, on the inner side there are about 10 minute spine-like hairs and, with two rather small black spines at the lower apex; metatarsi long and broad, distinctly longer than twice the length of the remaining ones together, slightly curved at the middle and with a long broad apical lower process which extends to the apical one-third of the second tarsal joint, the latter without distinct excision and apparently shorter than the two following joints together, the third joint slightly broader than the second, the fourth shortest, and the apical joint narrowest; pubescence rather more dense than that on the others, but without any special long paired hairs on the tarsi. Claws black, short and thick, with a blunt large process from the base as shown in the figure.

Wings clear, with the brown veins; the median vein forked near the base with a short stalk; the cubital vein divides itself into two at the apical one-third. Halteres dull-yellow.

Length of body: 2.1–2.6 mm. Length of wings: 3–3.5 mm.

Described from only one female collected in Taihoku, on the 29th of July, 1918. This is evidently a habitual blood-sucking species. The writer was bitten by it on his ear in a drawing room. This species somewhat agrees with BRUNETTI'S description of *aureohirtum*, but differs from that in many points as described above.

6. **Eusimulium geniculare,** sp. nov.

Pl. I, fig. 5; Pl. VIII, figs. 1-7.

Very near to *taipei* but easily distinguished by the short flagellar basal ring of antennae, the proportionally long first joint of fore tarsi on which there is no paired long hairs, etc.

♀. Head blackish, densely covered with a whitish dust. Frons and face as in the preceding species, but the pubescence whitish and on the latter there is no black hair. Back of the head covered with a dark brown dust and furnished with many brown hairs which are not intermixed with a black pubescence; vertex covered with a grey dust and furnished with a pale brownish pubescence. Proboscis brown, furnished with pale brownish pubescence. Palpi as in the preceding species, but blackish brown, furnished with a brown pubescence with the two apical joints covered with a greyish dust. Antennae comparatively short, yellow, somewhat obscured by a greyish dust; the first flagellar annulation conspicuously larger than the scape, distinctly broader than long and very slightly longer than the apical annulation which has two apical hairs as usual.

Thorax dark brown to black, with three very faint greyish longitudinal stripes, covered with a depressed whitish pubescence; shoulders brown to blackish brown. Pleurae paler than the notum, moderately obscured by a greyish dust, bare from pubescence but on the pro- and metapleurae there is a few yellowish pubescence; prothorax pale yellowish brown, furnished with a few yellowish pubescence. Scutellum brown, very slightly obscured by a greyish dust, along the posterior margin there is a row of a few long yellowish brown pubescence; metanotum brown, more or less covered with a whitish tomentum, bare from pubescence.

Abdomen blackish brown, obscured by a greyish dust and covered with a whitish pubescence, which is intermixed with very short blackish hairs toward the apical tergites; the basal scale yellowish brown, covered with a rather long yellowish white pubescence, and furnished with the usual fan-shaped row of much longer yellowish hairs towards each side; the under surface dull brown, with many short yellowish hairs.

Legs pale yellowish, with the tarsi blackish excepting most of hind metatarsi. Fore legs somewhat darker than the others; femora more or less pale yellowish brown at the middle of the exterior side, rather sparsely covered with a yellowish pubescence, without black hairs; tibiae slender and longer than the femora, brownish toward the apex, very sparsely covered with a brownish pubescence; tarsi very slender, entirely blackish, the first joint 2½ times as long as the 2nd joint or 1½ times as long as the three following joints together, covered with a blackish pubescence, and without paired long hairs. Middle legs paler than the fore legs; femora with a distinct blackish apical portion, furnished with yellowish and blackish hairs, the blackish ones mostly on the upper side; tibiae with a distinct blackish end, pubescent as in the femora but the blackish hairs much more conspicuous; tarsi slender, entirely blackish, covered with a blackish short pubescence, the first joint shorter than twice the length of the 2nd joint. Hind legs coloured as in the middle legs, but the metatarsi pale yellow and with the apex blackish, and the blackish portion of the femora and tibiae larger and more conspicuous; metatarsi nearly 2½ times as long as the four following joints together, covered with a dense yellowish pubescence, with the rather short lower apical prolongation which does not reach to the middle of the 2nd tarsal joint, the latter is as long as the two following joints together and has a distinct basal excision. Claws of the hind legs as in the preceding species, but a little narrower and its basal process distinctly curved.

Wings clear, with the yellowish brown veins; medial vein without stalk; cubital vein forked a little after the middle. Halteres pale yellowish.

Length of body: 1.8-2.3 mm. Length of wings: 2.3-2.6 mm.

Described from four females collected in Taihoku (III, V, XII); type in the Entomological Museum of the Government Research Institute, Taihoku, Formosa. The present species is also a real blood-sucking fly, biting man.

7. **Eusimulium bonninense,** sp. nov.

Pl. VIII, figs. 8-12.

The present species is very characteristic in the black antennae.

♀. Head blackish, with a whitish dust excepting on the lower half, Frons triangular, with a silvery whitish tomentum, about three-fourths as wide as long, covered with many rather depressed blackish pubescence, which is short and inconspicuous, but when seen from above conspicuous at the middle of the upper and lower halves. Face quadrate and the lower margin slightly concave, conspicuously covered with a silvery white tomentum and furnished with a somewhat sloping scattered pale yellowish brown pubescence, which is about three times as long as blackish hairs on the frons and extends up to the frons along the side. The elevation around the antennal fossae silvery white as in the face. Vertex hardly covered with any hairs, but at the side with a very few paler hairs similar to those on the face. Postocular bare rim moderately broad, slightly whitish tomentose but almost none on the lower half, practically equal in width through the whole length although the lower end is not well-defined, behind that there is a rather dense black ciliation which becomes rather sparser towards the jowls and extends behind the vertex. Proboscis brownish, conical, with the end minutely serrate. Palpi furnished with many blackish short but stout hairs, especially on the hind joint. Antennae throughly brownish black, covered with dense, short, curved blackish hairs; the first annulation of the flagellum much shorter than the scape which is about as long as the top annulation of the styli; the annulations of the styli very conspicuous. Eyes bare, with the facets all practically equal in size.

Thorax dull black, obscured by a yellowish grey depressed pubescence which is more conspicuous at the upper base of wings; the shoulders conspicuously brown; the sides quite bare, but greyish dusted. Scutellum brown and slightly palened towards the end, with two long black hairs at the lateral margin, which are slightly curved at the tip and are directed obliquely latero-dorsally. Postnotum black, haired as on mesonotum.

Abdomen black, along the apical margin of each segment somewhat paler, slightly obscured by a pale yellowish short pubescence which is intermixed with many long black hairs, and becomes longer at the side and apex; the anal segment pale brownish, furnished with many short pale yellowish grey hairs, but with no black ones, usual fan-shaped row of yellow hairs towards each side on the pale yellowish brown basal scale.

Legs normal, brownish. Fore legs darker than the others, the coxae slightly yellowish but not conspicuous, the fourth tarsal joint yellowish and somewhat conspicuous, the metatarsus rather slender, gradually widened towards the apex which is a little narrower than the broadest part of the 2nd joint, and as long as the four remaining tarsal joints together; femora broad, very little shorter than the tibiae; the 2nd tarsal joint distinctly shorter than the two following tarsal joints together, the fourth joint deeply bilobed at the tip, where it is conspicuously yellow. Hind legs paler than the fore legs, with the basal half of the metatarsus yellowish but not well-defined; tibiae longer than the femora but very much narrower; tarsi much longer than the tibiae, with the extreme base of the second joint, and the third joint yellowish, the metatarsi not straight but practically equal in width through the whole length and its ventral apex produced distinctly, about twice as long as the following tarsal joints together; coxae brown as in femora. Middle legs usual brown, the tibiae and tarsi slightly darker, the trochanter paler as in the fore or hind legs. Pubescence mostly yellowish brown, very short and oblique, on the upper side there are long rather depressed darker hairs intermixed with a few very long hairs on tibiae and metatarsi, the trochanter furnished with many long yellowish hairs; on the hind metatarsi there is a row of 10 distinct short but stout black hairs at the outer lower margin; the remaining tarsal joints covered with numerous somewhat long sloping hairs on the upper surface. Claws black, moderate in size, a stout process from the base as in figure.

Wings clear, slightly irridescent; medial vein forked at the base, without any stalk; cubital vein forked after about two-thirds from the base.

Length of body: 1.8 mm. Length of wing: 2.0 mm.

Described from only a single female collected by Prof. Dr. S. MATSUMURA, on the 20th of August, 1905, in Ogasawara Island. It is doubtful whether this species is a bloodsucker, but it may be so according to a letter from a agriculturist of this Island.

Genus **STILBOPLAX**, ENDERLEIN

Zool. Anz., LIII, p. 44 (1921).

Genotype: *S. speculiventris*, ENDERLEIN

Key for the our species

Front tarsi more or less flattened; hind claws rather broad and short.. *5-striatum*, sp. nov.
Front tarsi cylindrical; hind claws very long and narrow......... *equinum*, LINNAEUS

8. **Stilboplax equinum**, LINNAEUS

Pl. I, fig. 4.

Culex equinum, LINNAEUS, Syst. Nat., Ed. X, p. 603 (1758).
Atractocera lineatum, MEIGEN, Klass., I., p. 95 (1804).

♀. Head greyish white. Frons nearly triangle, sparsely covered with a pale yellowish white, about as long as wide, the incisions just above the antennal fossae conspicuous, at the lower border there is an inconspicuous very short longitudinal furrow. Face round and about as long as wide, furnished with a white pubescence which is slightly longer than that on the frons, the transverse furrow between the frons and the face distinct, rather broad and black. Vertex convex, covered with a whitish dust as on the frons or face, but there is no conspicuous pubescence. Postocular portion conspicuous and broad, covered with a whitish dust and a white pubescence which is intermixed with a few long black hairs, and there is nearly no bare rim through the whole margin. Proboscis brownish black, about a half as long as the head, and about $\frac{3}{4}$ times as wide as long, the apex furnished with 6 black minute teeth, covered with a very few short black pubescence. Palpi blackish, long and 5-jointed; first joint as long as the second, but a little broader, with a few long blackish hairs at the inner apex; second joint short and cylindrical, furnished with a very few long hairs at the outer side; third joint thickest, as long as the fourth, covered with long hairs, and with a distinct large short-elliptical sensory vesicle near the base; fourth joint distinctly narrowed at the base, furnished with hairs similar to those on the preceding joints and transversely striated through the whole surface but at the inner surface very indistinctly, at the apex there is an elliptical sensory vesicle which is about as large as that on the third joint; fifth joint slender and slightly shorter than two preceding joints together, the middle third slightly constricted but not well-defined, the surface transversely striolated and sparsely haired. Antennae blackish or brownish, with two basal joints paler, densely covered with numerous minute pollens intermixed with a few conspicuous pubescence, the tomentum being not apparent on the two basal joints, but on the second joint furnished with a few stout hairs at the apex. Eyes black, rather small, without pubescence and with the facets all practically equal in size.

Thorax greyish with 3 distinct brown longitudinal stripes, of which the middle one extends from the fore margin to the hind margin and the side-ones end rather a long way in front of the hind margin of mesonotum, slightly divergent behind and bent outwards before the fore margin; when seen from right above these stripes are united with a broad well-defined posterior band which could not be seen from posterior side; pleurae dusted as on the mesonotum but slightly darker; pronotum ashy-grey, conspicuous; shoulders large, somewhat darker than the notum; scutellum blackish brown, slightly obscured by a greyish dust, along the upper base there is a distinct transverse shining dark castaneous ridge; metanotum (mesothoracic postnotum) slightly paler than the scutellum, a transverse ridge between metanotum and scutellum brown and shining. Pubescence on the thorax pale yellow and depressed; on the pleurae not apparent but on the membranous area and just below the wing-base there are some long soft whitish yellow hairs; on the prothorax pale yellow; on the metanotum absent.

Abdomen greyish black, with 4 basal segment much greyer, covered with a depressed pale yellow pubescence which becomes sparser towards the base and is intermixed with a very few long black hairs on the apical segments; the basal scale brown, furnished with a fan-shaped row of yellowish white hairs; belly yellowish brown or reddish brown; genitalia with two minute, elliptical, black-pubescent cerci.

Legs brownish black or brown, with the apex of femora, the base and middle part of tibiae, the first joint of two posterior tarsi excepting of the apex, and the base of the remaining tarsal joints, yellowish; fore femora a little shorter than the tibiae but slightly broader, furnished with some black stout hairs on the upper side; fore tibiae along the upper side with a few black hairs which are shorter and much more inconspicuous than those on the femora; the first fore tarsal joint not specially dilated, shorter than the remaining ones together, with a short black spine at the lower apex and with two long hairs near the upper apex: the second fore tarsal joint longer than the third, and both with a minute spine at the lower apex, the first hind tarsal joint slightly dilated, with a broad lower apical process, furnished with a row of minute spines along the lower side and with a few long hairs at the upper apical portion; the second hind tarsal joint broad, with a very shallow dorsal excision just before the middle, with three short spines near the apex of underside; the third hind tarsal joint a little longer than a half the preceding joint, broad, with a minute spine at the lower apex; claws slender, conspicuously thickened at the extreme base. Pubescence on legs mostly paly yellowish, but on the black portions black, and on the upper side of tarsi longer.

Wings moderate in size, colourless and irridescent; veins usual, the medius connected with the radius by a very short stalk; cubital vein forked at the apical one-third. Halteres fresh yellow, with long stalk.

Length of body: 1.8-2.2 mm. Length of wings: about 2 mm.

♂. Velvet-black. Head slightly narrower than the thorax. Eyes bare from pubescence, closely contiguous from vertex to the base of antennae, with the large facets occupying the entire upper half, and are about two and a half times as large as the smaller ones in diameter, and with a curved conspicuous line of separation. Face dark brownish black, triangular and slightly longer than wide, with the nearly straight lower margin and the pointed upper angle which becomes very narrow and is upwardly produced through the antennal bases, furnished with a very few inconspicuous pubescence. Proboscis blackish with paler base, moderate in size, longer than wide, pentagonal with the shortest apical margin where there are two very inconspicuous minute processes at the side-angles, one at each angle, the side with many somewhat shaggy hairs. Palpi blackish, with black pubescence which is mostly conspicuous on the second and third joints. Antennae short and thick, 11-jointed, blackish, but the flagellum somewhat yellowish, covered with numerous comparatively long pubescence.

Thorax velvet-black, slightly obscured by a very fine brownish golden pubescence, with the sides and hind margin slightly brownish and covered with a few greyish dust, and with the whitish shoulders; pleurae brownish black, covered with a greyish dust, at a point below the wing-base and on the pronotum there is a somewhat conspicuous whitish tuft of hairs, and on the lower parts of pleurae a few inconspicuous pubescence. Scutellum dark brownish black, somewhat pubescent, postnotum paler than the scutellum.

Abdomen velvet-black, furnished with a few black pubescence, the ventre slightly paler than the dorsum; the basal scale black, with the usual fan-shaped row of blackish hairs; genital part slightly brownish, furnished with short paler hairs, and with short and small claspers, which are rather broad and have narrowed apices where there is a very few pubescence.

Legs short and thick, darker than in the female.

Wings as long as the length of body; halteres dull yellow, with the conspicuously large knob which is angularily curved inwards.

Length of body: 1.3 mm. Length of wings: 1.3 mm.

Described from one male and 9 females, collected at Kodakasaka, Kochi-prefecture, on the 22nd of July, 1919, and one male and 16 females from Ichibu, Kumamoto-prefecture, 4. VIII, 1919. This small species is a real blood-sucking insect, mostly bitting cattle or horses, and sometimes also human beings.

9. **Stilboplax 5-striatum,** sp. nov.

Pl. III, figs. 2, 4; Pl. X, figs. 1-9

Near to *Simulium latistriatum*, WHITE, and *S. striatum*, BRUNETTI, but at once distinguished from the both by the coloration of legs; from the former by entirely setose radial vein (I do not know that *S. striatum* belongs *Stilboplax*).

♀. Head greyish black. Frons somewhat triangular with nearly straight sides, greyish black but when seen from some directions it is slightly silvery white, about as long as 1½ times the width of its broadest part and longer than 5-times the width of its narrowest part, at the point where it is not sulcate longitudinally, furnished with some short dark pubescence which becomes rather conspicuous at the sides. Face round, slightly longer than wide, with the straight lower margin and a short upper prolongation which does not reach to the lower margin of frons, densely covered with a silvery white dust and with many rather longer sloping black hairs which are wanting just below the upper process. Vertex convex, covered with whitish dust and dark pubescence as on the frons. Postocular bare rim not conspicuous, slightly covered with a silvery white dust, behind that there is a conspicuous ciliation formed by rather long black hairs which become distinctly shorter towards the lower half of the head where the rim could not be seen clearly. Proboscis short and thick, about as long as wide, but pointed apically; the labrum epipharynx yellowish, with a few short black hooks; the epipharynx narrow, yellowish, furnished with a tuft of yellow short, minute, bristly hairs; the paraglossa broad and very short, blackish, covered with a black pubescence. Palpi blackish, furnished with many brownish hairs which become shorter towards the apex; the first joint short and narrow, not throughly pubescent but with a large tuft of long stout hairs on the outer side; the second joint broadest and about as long as the third, mostly pubescent, with the sensory vesicle moderate; the third slightly thickened towards the apex and minutely transversely striate, about half as long as the apical joint which is narrowest and is conspicuously curved below, at the apex with an indistinct sensory vesicle which is about a half as large as the preceding one; the 4th joint at about the middle one-third constricted, the lower side without pubescence. Antennae brown with the two basal joints distinctly yellowish-red, covered with numerous very short minute blackish pubescence on the upper side; the first joint smallest; the second joint slightly smaller than the first annulation of the flagellum, and furnished with many conspicuous hairs at the apical area; the flagellum rather broad, with the second annulation broadest and with the first one longest, the apical annulation narrowest but slightly shorter than the first and with a few stout but minute pubescence. Eyes bare from pubescence, with the facets all practically equal in size.

Thorax greyish, with 5 distinct longitudinal black stripes of which the three middle ones are slightly broader than the outer two, these stripes being united with a broad not well-defined transverse band along the hind margin and not reaching to the fore-margin, the surface densely covered with numerous depressed golden yellow pubescence; the shoulders slightly brownish but one specimen from Suisha quite black; the pleurae bare from pubescence, but covered with greyish dust; pronotum black, furnished with a distinct tuft of long and shaggy yellow hairs; scuttellum flat-triangular, black but very slightly tinged with brown, covered with many depressed golden yellow hairs, at the basal half of the sides there are some long bristly blackish hairs, and at the apex no pubescence; metanotum paler than the scutellum, pubescent as on the latter.

Abdomen velvet-black, with the three apical segments shining brownish black and furnished with somewhat erect short black pubescence, the remaining segments not distinctly covered with any hairs and minutely longitudinally striate; the basal scale yellowish brown, furnished with fan-shaped row of pale yellowish hairs; the genital part dull blackish, with a few pubescence.

Legs dark brown with the blackish coxae of which the fore one is pale yellow. The fore legs black, with the femora brown, paler toward the base; femora a little shorter than the tibiae, which are longer than the first joint of the tarsi and have very short curved spines at the lower apex; tarsi broad, the first joint gradually broadened apically and about 2.4 times as long as following joint, the third joint distinctly shorter than the second and about as long as the two following ones together; pubescence black but on the femora nearly all pale yellowish and on the tibiae there are some yellowish hairs on the under surface, the pubesence on the inferior internal side conspicuously shorter than on the outer sides. The middle legs brownish black, with the base of tibiae yellowish, and with the tarsi yellowish but the three apical joints and the apex of each of the two basal joints brownish; femora a little longer than the tibiae; tibiae broad, with a long black spine at the lower apex, and the inner apex furnished with four or five short black spines; tarsi apparently longer than the tibiae, the first joint about two-thirds as long as the tibiae, narrow and furnished with a row of very short black spines, at the inner side of these spines there is another row of similar ones at the apical portion, the second joint about twice as long as the third, and with two somewhat long black spines on the inner apical portion and a row of similar but much shorter ones on the whole outer-lower margin, the third joint as long as the fourth and furnished with a few short black spines at the lower apex, the fourth flat and wide and without any spines, the fifth narrow and slender, about one and a half times as long as the femora; pubescence fine and pale yellowish, intermixed with many long black hairs at the outer and upper sides, on the tibiae there are a few longer hairs at the upper apical area of each joints. The hind legs coloured as in the middle ones but slightly darker; the femora distinctly longer and slightly wider than the tibiae gradually broadened towards the apex but at the apical one-fourth conspicuously narrowed, with two thick black apical spines, and furnished with many short black spines at the lower apical portion; tarsi much longer than the tibiae, the first joint a little shorter than twice the length of the following joints together, moderatel widened, with a broad apical process at the inner side, the lowe side furnished with a row of short black spines which are usuall about 10 in number, and at the upper side there are a few ver long hairs at the apical portion, the second joint longer than the third and with a distinct dorsal excision near the basal one-third the lower apex with two distinct stout black spines and with two conspicuously long hairs near the excision, the third joint a little shorter than the fourth and with one long black lower apical spine and two long apical dorsal hairs, the fourth flat and wide as in the middle legs and without any long spines or long hairs, the fifth slender but widened towards the apex; pubescence pale yellow, intermixed with many longer black hairs on the upper side especially at the apical portion of each joint, on the upper apical part of each tarsal joint there are numerous black hairs which are somewhat bristly. Claws black, moderate in size, with a very short but thick notch at the base.

Wings colourless, comparatively small, irridescent; veins usual, the branches of the medius connected with the radius by a rather long stalk; cubital vein forked just after the middle of the whole length. Halteres pale yellow.

♂. Head about as wide as the thorax. Face roundish, with the blunt upper angle and the broad straight lower margin, greyish white, covered with some blackish pubescence which extends up to the vertex along the suture between the eyes, a similar one on the inconspicuous very small frons just above the antennae, at the upper angle of the face there is a conspicuous tuft formed of a few long blackish hairs. Vertex inconspicuous, but there are rather many long erect yellowish hairs. Eyes large, closely contiguous from vertex to just above the antennae, with the large facets occupying the entire upper half, the dividing line distinct and nearly straight; the large facets about twice as large as the smaller ones in diameter. Antennae blackish brown, with the two basal joints yellowish, when seen from a certain direction slightly greyish white, and densely covered with a minute soft pubescence. Palpi blackish brown, slenderer than in the female, with the 2nd joint conspicuously broader than the third; sensory vesicle on the 3rd and 4th joints. Proboscis yellowish brown, short.

Thorax black, the middle one-third shining, the anterior one-third velvet-black, not shining and with the shoulders broadly blue greyish white dusted, the inner corner of this spot roundish and its outer margin when seen from above deeply incised, just behind the shining area there is a blue greyish white dusted transverse band which has an irregular fore margin and a forwardly curved posterior margin, the following posterior part shining, the sides slightly grey-dusted broadly; pubescence short and bright yellow, intermixed with somewhat long erect black hairs, on the shining middle part rather sparse. Pleurae somewhat greyish, almost no pubescence. Scutellum blackish, furnished with numerous long erect black hairs, especially at the side, at the base there is a fine but conspicuous whitish transverse ridge. Postnotum dull brownish black, with the base slightly dusted greyish, between the scutellum and the postnotum there is a thick greyish transverse elevation.

Abdomen deep black, covered with a blackish pubescence which becomes denser and longer at the basal segments; the basal scale black, with brownish black fan-shaped side hairs; the first segment with a silvery white dusted patch on a point near the side of the posterior margin; the fourth and fifth segment with one pair of oblique bands which are silvery white dusted; the bands on the fifth being larger than those on the preceding segment. Genital part dull black; the claspers slender, slightly depressed, furnished with brownish black hairs and at the inner apex with a very inconspicuous black spine.

Legs blackish, with the front coxae, the trochanters, the extreme base of tibiae and the basal part of each tarsal joint of four posterior legs, yellowish. Fore femora brownish, covered with numerous long blackish hairs which become shorter toward the base; the tibiae as long as the femora, broadest at the middle, densely covered with a very short yellow pubescence which is intermixed with a very few long erect hairs especially on the upper-side; the tarsi slender, covered with a short depressed yellow pubescence, intermixed with many somewhat long black oblique hairs at the upper margin, and at the lower side there are nearly no bristly hairs. Hind femora broad, toward the base conspicuously narrowed at the apex slightly narrowed, apparently longer than the tibiae, covered with numerous black hairs which become conspicuously longer toward the upper base; the tibiae gradually thickened hindwards, broadest at a point two-thirds from the base, from which point it is slightly narrowed apically, covered with a yellowish brown pubescence, at the upper margin there are numerous long black hairs and at the lower margin many rather depressed shorter black hairs which extend on the sides, with two thick but rather short black spines at the apex of lower margin; hind metatarsi broad but slightly narrower than the tibiae, about two-thirds as long as the tibiae and about twice as long as the following tarsal joints together, more than the basal half yellowish with lower margin blackish, where there is a row of short black spines and many black hairs, covered with numerous short somewhat depressed pubescence which is yellowish on the yellowish portion and on the blackish portion blackish, at the upper margin intermixed with longer black hairs, two pairs of those are conspicuously long and somewhat erect, the apex of metatarsi shortly produced apically; the second tarsal joint near the base incised above, the basal portion yellowish and covered with yellowish pubescence, the apical portion blackish covered with yellowish pubescence intermixed with many black hairs which become longer and more conspicuous at the upper margin, at the apex of the lower margin there are four black spines; the third tarsal joint slightly shorter than the second, blackish brown, without yellowish area, covered with similar pubescence and hairs, only one apical spine; the third tarsal joint shortest and less pubescent or haired, the apical tarsal joint as long as the third, pubescent or haired as in the preceding one. Claws black, slender, without any process at the base. Middle legs as the hind-legs, but slenderer and slightly paler, with the metatarsi conspicuously slenderer and yellowish excepting the apex which is blackish.

Wings a little longer than the length of the body, hyaline, with yellow veins. Halteres yellow, with the long stalk brown.

	♀	♂
Length of body	2.5-2.7 mm	2.4 mm
„ wings	2.3-3 mm	2.6 mm

Described from one male and one female collected at Kappansan, Shinchiku-Prefecture, on the 26th of March, 1920; from two females at Kanshirei, Tainan-Prefecture on the 20th of February, 1917; from one female at Suisha, Taichu-Prefecture, on the 31st of May, 1917; from two females at Arisan, Tainan-Prefecture, on the 25th of April, 1917; from two females at Funkiko, Tainan-Prefecture, on the 2nd of October, 1918. Types are preserved in the Entomological Museum of the Government Research Institute, Taihoku, Formosa.

Two females from Arisan with the hind tibiae conspicuously yellowish on the basal one-third, and two females from Funkiko with the hind tibiae slightly yellowish at the basal one-fourth.

The present species is also allied to BRUNETTI's *grisescens* from Kursong in India, but it is easily distinguished from that by the absence of any ash-grey band on the posterior margin of the thorax.

Genus **ODAGMIA,** ENDERLEIN

Zool. Anzeiger, LIII, p 45 (1921).

Genotype: *Simulium ornata,* Meigen

Key to the our species

1. Hind tibiae yellowish for more than the basal half.
    2. Mesonotum without distinct greyish patch on the shoulders; frons shining.
        3. Tooth of claws straight...*bidentata,* sp. nov.
        33. Tooth of claws curved...*oitana,* sp. nov.
    22. Mesonotum with a distinct greyish patch on the shoulders; frons dull-coloured; tooth of claws curved .... *iwatensis,* sp. nov.

11. Hind tibiae blackish, with the base somewhat yellowish.
    2. Antennae blackish, with the three basal joints reddish yellow; tooth of claws curved..*karenkoensis*, sp. nov.
    22. Antennae yellowish, with the blackish tip; tooth of claws very short and straight .. .. *japonica*, sp. nov.

10. **Odagmia bidentata,** sp. nov.

Pl. IV, fig. 6; Pl. IX, fig. 11; Pl. X, figs. 10–13.

Rather near to *hackeri*, *Edwards*, but at once distinguished by the coloration of legs; also somewhat allied to *ornata*, MEIGEN, but easily recognized by the very small body, the coloration of legs and the absence of any grey patch on the shoulders.

♀. Head blackish, obscured by a greyish dust. Frons shining blackish, entirely covered by a greyish white dust, along the eye-margin furnished with a very sparse erect blackish pubescence which is not found near the antennal fossae. Face nearly quadrate, longer than wide, somewhat brownish, densely covered with a whitish dust, and furnished with sparse blackish hairs which become longer and more conspicuous towards the lower corners. Vertex obscured by a greyish dust, and furnished with sparse minute curved blackish hairs which become quite erect on the occiput. Back of the head blackish, obscured by a greyish dust, and furnished with some blackish pubescence which becomes conspicuous along the eye-margin, with no postocular bare rim. Proboscis yellowish brown, shining but obscured by a greyish dust on the paraglossa, about as long as the face; labrum provided with a few blackish short bristly hairs at the tip, in the rest conspicuously longer than the paraglossa which is blackish and has the yellowish apical surface, round the surface there are some dark tiny hairs. Palpi unicoloured, brownish black, somewhat obscured by a greyish dust, furnished with a dense, very tiny, somewhat pale and nearly erect pubescence, and covered with many long blackish hairs which become sparser and shorter on the apical joint; the two basal joints small, nearly bare from pubescence but with same long hairs; 3rd joint dickest, slightly longer than the following one, with small sensory vesicle about the middle; 4th joint about half as long as the 5th, and about twice as wide as the latter; the apical joint long and slender, gradually somewhat narrowed toward the apex. Antennae yellowish brown, with the two basal joints and one or two basal annulations of the third joint quite yellow; the basal annulation of the 3rd joint about as long as its apical annulation which is furnished with 3 apical curved hairs. Eyes with facets all practically equal as usual.

Thorax shining black, entirely obscured by a greyish dust, especially on the fore and lateral margins, and covered with a depressed golden yellow pubescence, with no stripe. Proscutum brown or reddish brown, obscured by a greyish dust, somewhat furnished with a yellowish pubescence. Pronotum brown or reddish brown, obscured by a greyish dust and furnished with an inconspicuous dark pubescence. Prothoracic episternum brown or reddish brown, obscured by a greyish dust. Episterna and epimera of meso- and metathorax dark brown, entirely obscured by a greyish white dust. Postparapterum dark brown, furnished with a tuft of blackish hairs. Scutellum brown, obscured by a greyish dust, sparsely covered with some yellowish pubescence, and along the posterior margin provided with some black bristly hairs which become conspicuously long at the sides. Postnotum darker than the scutellum, obscured by a greyish dust, with no pubescence.

Abdomen brown, with the dorsum blackish and with the ventre paler; the first segment yellowish, with an inconspicuous silvery-grey patch; 2nd-4th velvet-dark-brown, furnished with some pale pubescence; the 4 apical segments shining brownish black, entirely obscured by a greyish white dust, covered with blackish pubescence which becomes erect and longer at the sides; the basal scale yellowish brown, furnished with a row of fan-shaped yellowish hairs at each side; genitalia blackish.

Legs orange yellow, with the coxae of middle and hind legs, the apex of the femora and tibiae, the tip of the middle and hind metatarsi, and the front tarsi, blackish, somewhat greyish dusted and rather densely yellowish pubescent. Front legs rather broad; the femora broadest about the middle, slightly brownish at the apical area where is some blackish pubescence, on the upper margin there are two or three long black hairs; the tibiae narrower than the femora but longer, with about apical one-third blackish, on the outer surface there is a conspicuous silvery-grey patch which extends from the base to the apex, and there are about three long black hairs, the pubescence on the dark area partly blackish; the metatarsi about as wide as tibiae, gradually broadened apically, somewhat shorter than the 4 following tarsal joints together, the pubescence all blackish, on the outer side there are numerous conspicuous black hairs and one pair of enormousely long black hairs near the apical margin; the 2nd tarsal joint about half as long as the metatarsi and narrower than the latter, about half as wide as long, with numerous black hairs on the outer side, the pubescence all blackish; the 3rd tarsal joint shorter than ⅗ the length of the 2nd joint and narrower than the latter, haired as on the metatarsi; the 4th tarsal joint about half as long as the preceding one, black pubescent; the apical tarsal joint conspicuously shorter than the 3rd joint, with toothed claws. Hind legs not very broadened; the femora at the apical short portion brownish, the pubescence all practically pale yellow; the tibiae slightly curved, gradually broadened towards the apical portion but the apex quite narrowed, about ⅖ apical area blackish brown, on the outer side there is a silvery-grey patch which does not extend to the apical end, the pubescence pale yellow intermixed with a blackish one on the dark portion, on the outer side there are about 4 enormousely long blackish hairs and a small tuft of short black hairs near the apical margin, the apical spines rather long and conspicuous; the metatarsi long and rather slender, about twice as long as the following tarsal joints together, and about 1½ times as long as the front metatarsi, with the under margin and the apical one-third blackish, but the outer side thoroughly yellowish, the pubescence yellowish white excepting for a blackish spot on the dark portions, on the outer side there is a row of about 13 short blackish spines, on the opposite side numerous blackish hairs and two very long paired blackish hairs, the apical prolongation rather large; the 2nd tarsal joint about as long as the 3rd front tarsal joint but conspicuously narrower than that, on the upper side there are numerous short blackish hairs and a pair of long blackish hairs, on the outer apical corner there are two conspicuous blackish tiny spines, the excision conspicuous near the base; the 3rd tarsal joint about half as long as the preceding one, haired and spined as on the latter, with one pair of long blackish hairs near the apical margin of lower side; the 4th and 5th joints as in the front legs; claws rather large, with two quite separated teeth at the base.

Wings hyaline, with yellowish usual veins; medial vein forked just after the middle. Halteres yellow.

Length of body: 1.8-2 mm. Length of wings: 2.4-2.5 mm.

Described from 6 females collected by the author at Jifuku, Yamaguchi-Prefecture, on the 28th of June, 1921; type in the Entomological Museum of the Government Research Institute, Taihoku, Formosa.

11. **Odagmia oitana,** sp. nov.

Pl. IV, fig. 5; Pl. XI, figs. 10-15; Pl. XIV, fig. 12.

Very closely allied to *variegatum*, MEIGEN, but easily distinguished by having no grey transversal band on the front margin of mesonotum, as well as by the broad triangular frons.

♀. Head narrower than the thorax. Frons shining blackish, obscured by a greyish dust, the upper area broadest and about $\frac{1}{3}$ as wide as the head, with a sparse pale pubescence. Face black, entirely obscured by a somewhat silvery grey dust, sparsely furnished with a pale pubescence. Vertex somewhat dusted, with a conspicuous pale pubescence which becomes blackish and longer on the occiput. Back of the head blackish, slightly obscured by a greyish dust and furnished with a pale pubescence, no distinct postocular bare rim. Proboscis short, with the yellowish tipped labrum which is about twice as long as wide, and with the pale brown paraglossa which is about $\frac{2}{3}$ as long as the labrum and is yellowish tipped, the both of them furnished with a distinct pale pubescence. Palpi slender, about twice as long as the labrum, dark brown, furnished with numerous bristle-like blackish hairs, which become rather sparser on the apical joint and 2 basal joints, but quite longer on the latter; the 3rd joint as long as the 4th and slightly broader than that, somewhat constricted after the middle, covered with a dense pale minute pubescence, the sensory vesicle rather small, about $\frac{1}{3}$ as long as the joint and placed near the base; the 4th joint slightly pale, about equal width throughout the length, two-fifths as wide as long, transversely striated; the 5th joint very long and slender, gradually narrowed towards the tip but very slightly constricted before the apex, about twice as long as the 4th, striated as on the preceding. Antennae dark brown, obscured by a greyish dust and furnished with yellowish pubescence which is especially conspicuous at the margins and the apex; the 1st joint slightly yellowish toward the apical margin; the 2nd joint conspicuously yellowish, broader and hardly twice as long as the basal joint; the basal annulation of flagellum longer than the scape, yellowish brown, the 2nd annulation with the basal area pale, the apical annulation slightly shorter than the basal one and narrower than the remaining annulations. Eyes bare from pubescence, with the facets all practically equal.

Thorax black, slightly obscured by a whitish dust which becomes dense and so conspicuous towards the fore margin as to be seen as two distinct transverse silvery-greyish patches, furnished with a golden yellow rather depressed pubescence; shoulders black but in some specimens slightly brownish, with a very small whitish patch; pleurae blackish, obscured by a whitish dust, but quite bare on the membranous area. Scutellum slightly brownish, obscured by a dust; postnotum black.

Abdomen black, with the very narrow brownish hind margin on each segment and yellowish basal area on the ventre, shining but obscured by a greyish dust, covered with a rather sparse black erect pubescence; the 6 basal segments furnished with a yellowish pubescence and a greyish dust on the hind margins at sides; the basal scale brownish, with the margin yellowish, furnished with a fan-shaped row of pale hairs. Genital part blackish, obscured by a greyish dust and covered with an inconspicuous yellowish pubescence; subgenital plate very broad and short, with an apical margin curved inwards; lateral plates furnished with some black hairs on the margin; cerci short and broad but extended beyond the end of subgenital plate, furnished with some black hairs at the round margin.

Legs dull yellowish, with the apex of tibiae and femora of front legs, the apex of hind and middle tibiae, most of hind and middle femora, the front tarsi, the apical area of hind and middle metatarsi, the 4 apical joints of hind and middle tarsi, and the hind and middle coxae, blackish. Fore legs about as long as, or slenderer than the hind legs; the fomora shorter than the tibiae but broader, somewhat brownish excepting for the basal area, covered with a yellowish pubescence, and furnished with a few blackish hairs at the upper outer surface; the tibiae longest in all joints, the blackish portion occupied on about $\frac{1}{3}$ apical area, on the yellowish portion there is a long silvery greyish patch, the pubescence yellowish and intermixed with a few long hairs on upper margin. Front tarsi conspicuously longer than the tibiae, all black; the metatarsi about as long as the remaining tarsal joints together and slightly shorter than the femora, rather narrow and gradually broadened towards the apex, covered with a very short yellowish pubescence, and on the underside furnished with rather dense black hairs which are intermixed with a few long hairs near apex; the 2nd joint about half as long as the metatarsus, haired as on the latter; the 3rd joint slightly shorter and narrower than the 2nd, haired like the preceding, with a very long hair near the lower apex; the 4th about half as long as the 3rd, covered with a yellowish pubescence and black hairs; the apical joint long and slender, about twice as long as the 4th, with short and long hairs. Hind legs broader than the front legs, covered with a yellowish pubescence; femora very slightly longer than the tibiae, broadest at the middle portion, on the basal one-third there are some long pale hairs on the upper margin; tibiae longer than the front tibiae, furnished with a few pale long hairs on the under margin, and with two short dark apical spines. Tarsi somewhat longer than the front tarsi; metatarsi yellowish, with the apical portion blackish, much longer than the front metatarsi and also the following joints together, broader than the front metatarsi and the following joints, with a distinct apical prolongation, and on the lower margin there are 4 very long hairs and on the upper margin more than 16 black tiny spines; 2nd joint blackish, with a yellowish base, about $\frac{2}{3}$ as long as the front 2nd tarsal joint and conspicuously narrower than that, with a distinct excision; 3rd joint blackish, about a half as long as that of the front tarsi, and about half as wide as long; 4th joint blackish, about as long as the 4th front tarsal joint, about as long as the 3rd but distinctly broader; apical joint blackish, with claws longer than the 2nd tarsal joint, long and slender, slightly longer than the front one. Claws proportionately large, at the basal portion with two conspicuous teeth, of which basal one is rather flat and is rounded, but the other one is narrow, curved and pointed.

Wings moderate in size, not conspicuously smoked, with the yellowish veins, excepting those on costal area; radial vein not divided into two; medial vein rather straight and forked near the base; cubital vein forked just after the middle; the basal cell not develped. Halteres pale orange yellow.

Length of body: 3.2–3.8 mm. Length of wings: 3.1–3.6 mm.

Described from 5 females, collected by the author at Oita, Oita-prefecture, in August, 1920; type in the Entomological Museum of the Government Research Institute, Taihoku, Formosa.

12. **Odagmia iwatensis,** sp. nov.

Pl. XI, figs. 6–9.

Very closely allied to *ornata*, MG., but quite easily distinguished by a very long apical joint of palpi, this being very different from other *Odagmia*-species.

♀. Head black, narrower than the thorax. Frons about one-third as wide as the head, black, obscured by a whitish dust, with some pubescence. Face roundish, brownish, obscured by a whitish dust, scarsely furnished with a pale pubescence. Proboscis slightly longer than wide, with the brownish labrum and the blackish paraglossa. Palpi long and slender, blackish; the 3rd joint somewhat shorter than the 4th but broader; the 4th rather slender, furnished with long hairs which are somewhat scarser than those on the preceding one; the apical joint very long and slender, about 3 times as long as the 3rd, the hairs much scarser. Antennae blackish with the two basal joints yellowish, obscured by a greyish dust.

Thorax black, obscured by a grey dust and covered with a yellowish pubescence, just behind the shoulders there are two large transverse-quadrate patches of whitish dust, which are quite separated at the middle of the notum and extend through the lateral margin, near the posterior margin there is an inconspicuous whitish band; shoulders brownish, obscured by a greyish dust; pleurae brownish, almost entirely obscured by a greyish dust, especially on the epimera and episternum; scutellum shining black, somewhat obscured by a greyish dust and furnished with a few pubescence; postnotum blackish, obscured by a greyish dust.

Abdomen black, with the brownish ventre, obscured by a greyish dust and furnished with a pubescence; the basal scale blackish, with pale margin which is furnished with a fan-shaped row of yellowish hairs.

Legs brownish black, with the coxae, the base of femora, about $\frac{3}{4}$ basal portion of front tibiae, about $\frac{2}{3}$ basal portion of four hind tibiae, the base of middle metatarsi, about half the length of hind metatarsi and the base of 2nd hind tarsal joint, yellowish, with a greyish dust and a whitish pubescence nearly throughout, but intermixed with a blackish pubescence on dark portions. Front legs nearly black, with a long silvery grey patch on the tibiae, with blackish long hairs on femora and a very few on tibiae; metatarsi about $\frac{2}{3}$ times as long as tibiae, somewhat broader than the latter; 2nd tarsal joint slightly narrower than the metatarsi, about half as wide as long, shoter than half the length of first tarsal joint; 3rd tarsal joint about as wide as the preceding one and abaut $\frac{-}{5}$ times as long as that; 4th tarsal joint about half as long as the 3rd and slightly narrower than that; apical tarsal joint somewhat longer than the 4th, with rather large claws. Hind legs with broad femora and tibiae, the former with about $\frac{1}{3}$ basal portion cospicuously yellow, and furnished with long blackish hairs at apical portion, and the latter with about half the basal portion distinctly yellow and furnished with a few long blackish hairs on under margin; the apical spines of tibiae conspicuous and curved; metatarsi yellow more than basal half, slightly shorter than the tibiae, about $1\frac{1}{3}$ times as long as the front metatarsi but slightly narrower, furnished with about 16 bristle like very minute but conspicuous spines at the upper margin, on the opposite side there are many long hairs; 2nd tarsal joint about $\frac{-}{6}$ times as long as the 2nd tarsal joint of front legs, about twice as long as the 3rd joint, the basal excision distinct; 3rd tarsal joint comparatively small, about half that of the front legs in length and width; 4th tarsal joint slightly shorter than the 3rd, but conspicuously broader; the apical tarsal joint long and slender, distinctly longer than the 3rd, and nearly the same as that of the front legs; claws blackish, with two teeth on the basal half, the apical one rather sharp and curved, the basal one large with round tip.

Wings hyaline, not smoked, with the veins in *oitana*; halteres pale yellowish, with the base brownish.

Length of body: 2.8–3.7 mm. Length of wings: 3–4 mm.

Described from only two specimens collected in Iwate, on the 20th of November, 1914: type in the Entomological Museum of the Government Research Institute, Taihoku, Formosa.

13. **Odagmia karenkoensis**, sp. nov.

Pl. IX, figs. 6–10.

Allied to *hackeri*, EDWARDS, but easily distinguished by long hind metatarsus.

Head conspicuously norrower than the thorax. Frons dark brown, moderately shining and slightly obscured by a greyish dust, furnished with a few blackish brown erect pubescence along the eye-margins, broader than ⅓ the width of head, slightly narrowed below, with rather straight sides. Vertex dusted and pubescent as on the frons, but the pubescence on almost the whole surface. Face oval, with the lower margin straight and the upper margin somewhat triangularily produced, covered with a dense white dust, and furnished with a sparse, rather long, somewhat sloping brownish pubescence throughout almost the whole surface. Back of the head shining black, slightly obscured by a greyish dust, furnished with a blackish pubescence which becomes conspicuous toward the eye-margins, no postocular bare rim. Proboscis a little shorter than the face, brown with the tip yellowish. Antennae blackish brown, with the two basal joints yellowish, obscured by a greyish dust and furnished with a very few blackish pubescence; scape distinctly shorter than the first flagellar annulation, the latter being shorter than the apical annulation which is provided with 3 tiny apical hairs. Palpi blackish, obscured by a greyish dust and furnished with many long blackish hairs; 3rd joint as long as the following one but distinctly broader, with a rather small vesicle before the middle; apical joint very long and slender, very slightly narrowed in the long medial portion, nearly twice as long as the 2nd joint. Eyes as usual.

Thorax black, entirely obscured by a greyish white dust, and covered with a depressed blackish brown pubescence, with no stripes. Proscutum blackish brown, with the posterior corner reddish brown, obscured by a greyish dust, and furnished with a few blackish brown pubescence; pronotum as in the proscutum but slightly darker. Prothoracic episternum brown, covered with a dense greyish dust and furnished with many curved yellowish hairs; the rest of the pleurae as in the prothoracic episternum but there is no hair excepting a blackish pleural tuft. Scutellum black, obscured by a greyish brown dust, furnished with many long black hairs; postnotum coloured and dusted as on the scutellum, but there is no hair.

Abdomen dull blackish brown, distinctly darkened toward the anal end, furnished with a short blackish pubescence; the basal segment distinctly covered with a silvery white tomentum; the four following segments distinctly longitudinally striated, the remaining segments being more or less shining; the basal scale brown, slightly covered with a greyish dust, furnished with many long yellowish brown hairs which on the lateral margin are very long and form a fan-shaped tuft; genitalia blackish and moderately pubescent.

Legs black, with the base of front femora, the basal half of the four posterior metatarsi, coxae and the base of the four posterior tibiae, all yellowish. Fore legs with a large silvery white patch on the tibiae; tarsi entirely black, furnished with black hairs; the metatarsi as long as the four following joints together, or longer than twice the length of the 2nd tarsal joint, with two long black hairs near the tip of the under surface; the 3rd and fifth tarsal joints furnished with a very long black hair near the middle of the upper surface. Hind legs broader than the front legs, furnished with a black pubescence; tibiae distinctly shorter than the femora, strongly narrowed at the base, the basal half yellowish at the point where the pubescence is yellowish, with a rather short silvery white patch; tarsi distinctly longer than the tibiae, with the basal half of the first and second joints yellow; metatarsi a little shorter than the tibiae and distinctly narrower, with a row of more than 16 tiny blackish bristles along the lower margin, and with a subquadrate apical appendage; 2nd tarsal joint nearly $\frac{1}{4}$ as long as the preceding one, with a slight excision near the base; apical joint with one very long hair on the upper middle; claws narrow and slightly curved, with a narrow and slightly curved subbasal tooth, and also with a short basal tooth.

Wings moderate in size, with the veins pale yellow, excepting those toward the costal area which is pale brownish; medial vein forked at the base; cubital vein forked just after the middle. Halteres yellow.

Length of body: 2.9 mm. Length of wings: 3.3 mm.

Described from only one female collected at Karenko, Formosa (20. VII. 1919); preserved in the Entomological Museum of the Government Research Institute, Taihoku, Formosa.

14. **Odagmia japonica,** sp. nov.

Pl. IV, fig 3; Pl. XI, figs. 1 5.

Black small species, with a silvery grey patch on tibiae, no stripes on thorax, bidentate claws, and usual venation which has short forked cubital vein. Closely allied to *argyreatum*, LDST., and *argentipes* EDW., but at once recognized by a distinct subbasal tooth of claws. This is a species which might be placed between *argentipes* and *fuscipilosum* EDW. The present species is also allied to *bidentata*, m., but distinguished by the blackish legs and the short fork of the cubital vein.

♀. Head black, obscured by a grey dust. Frons black, somewhat shining, slightly obscured by a greyish dust, furnished with a blackish pubescence which is quite sparse and conspicuous along the eye margin. Vertex dusted and pubescent as on the frons but the pubescence is very conspicuous and is longer. Face oval, with a very short median sulcus, shining black, entirely covered with a silvery-grey dust, and furnished with a sparse blackish pubescence which becomes longer and more conspicuous towards the lower margin. Back of the head shining black, slightly obscured by a greyish dust, provided with a black somewhat erect pubescence which becomes conspicuous on the occiput, no postocular bare rim. Proboscis blackish with the tip dull yellowish, obscured by a greyish dust, about as long as the face; labrum with brownish tip which is furnished with a blackish pubescence; paraglossa much darker than the labrum, the tip slightly pale and furnished with blackish hairs. Antennae orange yellow, gradually darkened towards the tip, covered with a greyish dust and a yellowish pubescence which becomes blackish on the apical annulations, with some black minute bristly hairs on the two basal joints, and with two curved black bristly hairs on the apical annulation of the third joint. Palpi dark brown, obscured by a greyish dust and covered with long blackish hairs; 3rd joint slightly longer than the 4th, somewhat broadened apically, with rather small sensory vesicle about the middle; 4th joint gradually broadened towards the apex, somewhat longer than half the length of the apical joint which is constricted at the middle one-third. Eyes as usual. Thorax somewhat shining, black, obscured by a greyish white dust, covered with a dense depressed black but yellowish-tipped pubescence which becomes much more yellowish on the posterior half, with no stripes. Proscutum blackish with the posterior corner somewhat yellowish, obscured by a greyish dust, furnished with a few blackish pubescence. Pronotum brownish black, obscured and pubescent as on the proscutum. Prothoracic episternum black, entirely obscured by a greyish white dust, and furnished with no pubescence. The rest of pleurae black, obscured by a greyish dust, but somewhat brownish at the wing bases, with blackish pleural tuft. Scutellum somewhat brownish, obscured by a greyish dust, covered with a very few blackish pubescence and provided with many long black bristly hairs on the margin which become conspicuously long at the sides. Postnotum darker than the scutellum, but much more obscured by a greyish dust and furnished with no pubescence.

Abdomen dark brown, with the anal end blackish; 2nd to 4th segments dull brown, more or less velvety, covered with a blackish pubescence; the remaining segments shining, obscured by a greyish dust which becomes silvery-grey and quite dense on the 1st segment, furnished with a blackish pubescence which becomes somewhat conspicuous on the four apical segments; ventre not distinctly paler than the dorsum; the basal scale blackish brown with a narrow pale margin, the fan-shaped hairs blackish; genitalia blackish, with black broad gonapophyes furnished with black pubescence.

Legs blackish to brownish, with the front legs (excepting of tarsi and apex of tibiae), and the about basal two-thirds of middle and hind metatarsi, yellowish; the pubescence almost all blackish. Front legs not very conspicuously broad; femora yellowish brown to brown, covered with a yellowish pubescence, furnished with blackish hairs especially on the apical half; tibiae quite yellow, with the apical $\frac{1}{4}$ portion blackish, covered with a blackish pubescence which becomes whitish on the outer side at the point where they form a long silvery grey patch, on the outer margin there are one or two long black hairs; metatarsi black, covered with black short and long hairs, near the apical margin with a pair of long black hairs, about as long as the following joints together and about 4 times as long as wide; 2nd tarsal joint about $\frac{2}{5}$ times as long as the preceding one, and about twice as long as wide, black haired and pubescent; 3rd tarsal joint longer than half the length of the 2nd and narrower than the latter, haired and pubescent as on the metatarsi; 4th tarsal joint about half as long as 3rd, black-haired; apical tarsal joint shorter than the 3rd, black-haired, with bidentate claws. Hind legs brown to blackish, with the trochanters pale; femora somewhat paled towards the base, entirely covered with a black pubescence, furnished with some long black hairs on the upper side; tibiae curved moderately, with a silvery-grey patch on the basal half, covered with a black pubescence, on the outer margin there are three or four very long black hairs, the apical spines brown, conspicuous but not very long; metatarsi about twice as long as the remaining joints together, narrow and long, dull yellowish white, with about $\frac{1}{4}$ apical portion blackish, covered with a yellowish pubescence which becomes blackish on the apical dark area, the outer side black-haired and with two long paired black hairs, the apical prolongation not very large, a row of about 10 spines conspicuous; 2nd tarsal joint rather narrow, about as long as the 3rd tarsal joint, brown, with the basal half yellowish white, the pubescence yellowish but blackish on the apical portion, with many black hairs, a pair of long black hairs and two black apical spines, the excision near the middle conspicuous; the 3rd tarsal joint shorter than half the 2nd, spined and haired as on the preceding one but the pubescence all blackish; two apical tarsal joint as in the front legs; claws with two not long teeth at the base.

Wings hyaline, with usual yellowish veins; cubital vein forked at the $\frac{1}{3}$ apical portion; halteres sap yellow.

Length of body: 1.5-2.0 mm. Length of wings: 2.0-2.5 mm.

Described from 14 females (Jifuku, Yamaguchi-Prefecture, 28. VI, 1921), 14 females (Nakagawara, Tottori-Prefecture, 10. VII, 1921), and 4 females (Yokote, Shimane-Prefecture, 9. VII, 1921), collected by the author. Type in the Entomological Museum of the Government Research Institute, Taihoku, Formosa.

Gen. SIMULIUM, LATREILLE

Hist. Nat. Ins. et Crust., Vol. 3, p. 426 (1802).

Atractocera, MEIGEN, Klass., I, p. 94 (1804).
Melusina, MEIGEN, Nouvelle Class., 1800 (nomen nudum).
Boopthora, ENDERLEIN, Deut. Tierarz. Woch., Hannover, No. 16, p. 199 (1921); Zool. Anz., LIII, p. 45 (1921).

Genotype: *Culex reptans*, LINNAEUS.

Key to the our species

1. Front tarsi flattened.
    2. Frons shining.
        3. Hind tibiae more than basal half yellowish.
            4. Mesonotum with black stripes.
                5. Claws of hind legs triangularily produced at the base; 2nd joint of front tarsi distinctly twice as long as wide.
                    6. Medial vein with a distinct stalk as usual......*annulipes*, sp. nov.
                    66. Medial vein without stalk, forked from the base...*katoi*, sp. nov.
                55. Claws of hind legs slightly roundly broadened at the base; 2nd joint of front tarsi about 1½ times as long as wide...*oshimanum*, sp. nov.
            44. Mesonotum without stripes; claws of hind legs triangularily produced at the base; 2nd joint of front tarsi about twice as long as wide...*nipponense*, sp. nov.
        33. Hind tibiae nearly whole or at least the apical half blackish.
            4. Mesonotum without stripes.
                5. Hind tibiae entirely blackish; claws of hind legs triangularily produced at the base.. *minutum*, ap. nov.
                55. Hind tibiae yellowish at the basal half; claws of hind legs roundly broadened at the base.. *venustum*, SAY
            44. Mesonotum with stripes; hind tibiae at the extreme base yellowish; claws of hind legs toothed................................. *ambiguum*, sp. nov.

22. Frons dull coloured, distinctly pubescent; hind tibiae yellowish, with the extremity blackish; claws of hind legs triangularily produced at the base; mesonotum without stripe ....*yokotense*, sp. nov.
11. Front tarsi cylindrical; frons shining; mesonotum without stripe.
2. Hind tibiae yellowish, with the apex blackish ....*nikkoense*, sp. nov.
22. Hind tibiae at the basal half yellowish....... ....*arisanum*, sp. nov.

15. **Simulium annulipes**, sp. nov.

Pl. IV, fig. 1; Pl. XII, figs. 8-14.

Black species, with the 5-striated mesonotum, the silvery-grey patch on tibiae and the annulated legs. Allied to *reptans*, L., *columbatczense*, SCHÖNB., *venustum*, SAY and *morsitans*, EDW., distinguished by the distinct black longitudinal stripes.

♀. Head conspicuously narrower than thorax, blackish. Frons narrow, the upper area broadest and about $\frac{1}{3}$ as wide as the head, narrowed below with nearly straight sides, the surface with an inconspicuous longitudinal middle groove which scarcely reaches to the lower margin of face and is conspicuous between two antennal fossae, black, obscured by a whitish dust, and furnished with a very few pale pubescence on the upper portion. Face oval, broadened below with round lower margin, black, entirely obscured by a silvery grey dust, and furnished with a sparse yellowish pubescence. Vertex broad, with two oblique inconspicuous short carinae (each one from the upper corner of eye), dusted as on the frons, covered with a few yellowish somewhat erect pubescence which continues into the back of the head, at the point where a very few black erect pubescence is seen near the eye-margin which has no distinct postocular bare rim. Proboscis dark brown, rather short, shorter than the face; labrum castaneous, with a very few pubescence at the apex; paraglossa dark, not reaching to the apex of labrum, with many conspicuous dark pubescence. Palpi blackish brown, obscured by a grey dust; the third joint short, about half as wide as long and very slightly longer than the fourth, covered with numerous blackish hairs which are intermixed with a few pale coloured pubescence on apical area, the sensory vesicle very small and occupied only one-third in length near the middle; the 4th joint slightly longer than half the length of apical joint but broader, widened apically, with rather dense transverse striation especially on lower surface and many blackish hairs which are less than on the preceding one, yellowish pubescence throughout almost the whole of the surface; 5th joint longest and slender, narrowed at the apical half but the apex slightly thickened, with numerous transverse stripes and many hairs which are sparser than on the 3rd joint. Antennae brown, with pedicel, scape and the basal flagellar annulation yellowish; the scape shorter than the first flagellar annulation, furnishled with blackish hairs, conspicuous on the lower surface and upper apical area, similar hairs on the pedicel; the apical flagellar annulation narrower and longer than the first annulation, with 2 apical curved hairs; pubescence yellowish, somewhat longer on the upper surface. Eyes bare of pubescence, with the facets all practically equal.

Thorax somewhat quadrate, slightly shorter than wide, black, obscured by a grey dust and covered with a dense yellow pubescence, with 4 equally separated black (bare from dust) stripes on the dorsum, two middle ones slightly divergent backwards and then both connected together near the posterior margin of mesonotum, two lateral stripes broadened forwards and continued into the shoulders, in the middle there is a very narrow but distinct black stripe which begins from near the centre of mesonotum and reaches to the fore margin; shoulders brownish, obscured by a somewhat silvery-grey dust; pronotum covered with a silvery grey dust; pleurae dark brown, nearly bare from pubescence, paler on the prothoracic episternum, on the prothoracic and mesothoracic episternum and on mesothoracic epimeron with silvery-grey patch; scutellum brownish, furnished with a yellowish pubescence; postnotum somewhat darker than the scutellum.

Abdomen black, with the pale basal segment, obscured by a whitish dust which becomes so conspicuously dense on the second joint that it appears as a silvery-grey patch and is bare on 3rd, 4th and 5th segments, covered with numerous black and yellowish somewhat erect pubescence which is conspicuous on the margins. Underside of abdomen brownish black, covered with a greyish dust and furnished with rather sparse pubescence especially on the apical margin of each segment. Basal scale brownish, furnished with a fan-shaped row of whitish hairs. Genital part brownish.

Legs blackish brown, with the front coxae, the trochanters, the base of femora, the basal two-thirds of the tibiae, the base of the middle metatarsi and the basal half of the hind metatarsi, all yellowish. Front legs shorter than the hind legs, a long distinct silvery-grey patch on the tibiae; femora shorter than the tibiae but broader, the yellowish area appearing only on the dorsal surface, furnished with blackish hairs which become long and conspicuous on the upper apical surface; tibiae covered with rather depressed yellowish white pubescence which becomes blackish on the apical blackish portion, the yellowish part occupying on about three-fourths the whole length of tibiae. Front tarsi black, rather broad, about as long as the coxae, the trochanter and the femora together; metatarsi longer than the three following joints together, on the under surface there are many short blackish hairs and on the upper surface a few sparse pale erect pubescence; 2nd joint shorter than half the length of the metatarsus, furnished with black hairs as on the preceding one, and covered with a very minute pale pubescence on the upper surface where a long hair is seen near the apex; the 3rd about two-thirds as long as the 2nd and narrower than that, furnished with short and long hairs like the preceding joint, but a conspicuously long hair at the middle of under surface; the 4th joint slightly shorter than the apical one, broadest, pubescent as those on the 4th but it is somewhat shorter; the apical joint distinctly shorter than the 3rd, hairy. Hind legs broader than the front legs, excepting for the tarsi; femora longer than the tibiae, covered with a yellowish white pubescence which becomes inconspicuous towards the inner surface and is sparsely intermixed with blackish hairs on the upper margin; tibiae covered with a pubesecence which is the same as that on the femora, and furnished with a few long hairs and very short bristle-like pubescence on the upper margin, the latter only at apical portion, the apical spines two, but very small and inconspicuous. Hind tarsi about as long as the femora and trochanters together, and also about as long as the front tarsi; metatarsi very long but shorter than the tibiae, about as long as the 2 basal joints of front tarsus united, on the lower surface there is a row of about 11 minute black spines and a rather long apical prolongation, the surface covered with numerous whitish pubescence which becomes somewhat longer towards the under surface where there are some long paired hairs, the yellowish portion occupies the whole basal two-thirds; 2nd joint conspicuously shorter than front 2nd tarsal joint, nearly divided in two by a distinct excision, its basal part yellowish and furnished with numerous yellowish hairs, the apical part about twice as long as the basal part, furnished with some bristle-like pubescence on the under surface and long hairs on the upper surface; 3rd joint slightly longer than half the length of the 2nd joint and about half as long as the 3rd joint of front tarsus, furnished as on the preceding one; 4th joint about as long as the 3rd, and somewhat smaller than the 4th tarsal joint of front leg; apical joint longer than the 3rd joint, about the same as that of the front tarsus. Claws as usual, with a basal tuberculation.

Wings very slightly smoked, with yellowish base; veins yellowish excepting for the costa brownish; radial vein not forked; medial vein forked very near the base; cubital vein forked long after the middle; basal cell not seen. Halteres pale orange yellow.

Length of body: 2.8–3.2 mm. Length of wings: 3.5–4 mm.

Described from 5 females, three of which were collected at Sapporo and others at Ziozankei, Hokkaido. The latter specimens are larger than the former. Four females from Sachalien also belong to the present species. Type in the Entomological Museum of the Government Research Institute, Taihoku, Formosa.

16. **Simulium katoi,** sp. nov.

Pl. III, fig. 3; Pl. VII, figs. 8-11; Pl. XII, figs. 15-16.

Allied to *Stilboplax 5-striatum*, m., but distinguished by the yellowish hind tibiae, the broad striation of mesonotum, the conspicuous whitish lateral stripes of thorax, the silvery white band of abdomen, and the apical spine of fore tibiae.

♀. Head greyish black. Frons black, obscured by a greyish dust, but shining when seen from some directions, sparsely furnished with very short erect blackish pubescence. Face oval, with the roundish lower margin and a short upper prolongation, black densely covered with a silvery white dust, and with many sloping black hairs which become longer toward the apical part, on the upper part bare from hairs. Vertex black, covered with a greyish dust, and with very sparse blackish hairs. Back of the head blackish, quite obscured by a greyish white dust, and furnished with a sparse black pubescence, no distinct postocular bare rim. Proboscis about as long as the face, reddish yellow; labrum pale, furnished with some blackish bristly tiny hairs on the apex; paraglossa pale reddish yellow; galea and mandibles blackish brown. Palpi blackish brown, slightly obscured by a grey dust, furnished with long blackish hairs; 3rd joint longer than the 4th and about twice as long as wide, near the middle there is a sensory vesicle which is moderate in size; 4th joint about 2½ times as long as wide, and about half as long as the 4th; apical joint long and slender, gradually narrowed towards the apibal part but the apex swollened. Antennae yellowish brown, with the 6 apical flagellar annulations blackish, obscured by a greyish dust, and covered with numerous curved blackish pubescence which is wanting on two basal joints which are furnished with a few straight blackish hairs on the apical margin; the basal flagellar annulation longest and widest; the apical flagellar annulation conical, slightly shorter than the basal one but narrower, furnished with 4 conspicuous apical curved hairs. Eyes bare from pubescence, with the facets all practically equal in size.

Thorax black, obscured by a greyish white dust, and covered with numerous depressed golden yellow pubescence, with 5 distinct rather broad longitudinal black stripes; the median one about half as broad as subdorsal stripes, hardly reaching to the fore margin; the acrostichal pair slightly narrower than the subdorsal stripes, slightly divergent hindwards, the apical ends straightly united to the median; the subdorsal pair reaching to the foremargin. All stripes stopping just after the level of the wing roots, and acrostichal pair curved inwards uniting with the median; silvery white stripes on the outer-margin of subdorsal stripes, broad and conspicuous, continuous to the foremarginal whitish band when viewed from above in front or at a low angle in rear but separated by the subdorsal stripe when viewed from above. When seen from above there are 4 broad blackish stripes on the thorax, which, when viewed from other directions, are greyish portions between the 5 black stripes. The posterior quarter of the dorsum grey, densely covered with a depressed golden yellow pubescence, but black viewed from the above. Pleurae black, obscured by a greyish dust; scutellum black, furnished with long black hairs on the hind margin; postnotum black, with a very narrow greyish band on the basal and apical margins.

Abdomen somewhat velvety brownish black, with the 3 apical segments shining black, and with a conspicuous broad silvery basal band; 2nd to 4th segments covered with very scarce erect short black hairs especially on the lateral portions; a round somewhat greyish marking on the middle of each segment, this being conspicuous when viewed from the above; the remaining segments covered with numerous erect black hairs which are longer than those on the basal segments; ventre slightly paler than the dorsum, the basal part brownish; the basal scale brown, furnished with a fan-shaped row of blackish hairs; genital part dull blackish, with a few pubescence.

Legs rather broad with a long silvery white patch on tibiae. Fore legs dull yellowish, with the apices of tibiae, and tarsi black; femora conspicuously shorter than the tibiae, brownish towards the apex, covered with numerous depressed golden yellow pubescence, which become blackish on the apex and is intermixed with same long black hairs on the upper margin; tibiae pale yellow, with the apical quarter black, covered with a depressed white pubescence which is intermixed with some oblique black pubescence on the lower margin and with two or three somewhat long erect hairs on the outer margin; tarsi broad, entirely black, covered with black pubescence; metatarsi about two-thirds as long as the tibiae and about as long as the following ones together, gradually broadened towards the apex, on the outer side there are some long black hairs and a specially long paired set of hairs near the apex; 2nd tarsal joint slightly shorter than the two followings together and slightly longer than one-third the length of metatarsi, furnished with some long black hairs on the outer side; 3rd tarsal joint about as long as the following ones together, haired as in the preceding one; the two apical tarsal joints slightly paler, covered with long black hairs on the upper surface. Hind legs broader than the fore legs, yellowish, with the apical two-thirds of the femora, the apical one-third of the tibiae and the metatarsi, and the four apical joints of the tarsi, all blackish, covered with yellowish pubescence which becomes blackish on the blackish portions; femora conspicuously longer than the tibiae, furnished with some long black hairs on the black portion; tibiae nearly as long as the metatarsi, on the outer margin there are two pairs of long black hairs, of which one is near the base and other is on the apical border of the yellowish part, some black hairs on the outer side of black portion, the two apical spines black and rather short; metatarsi curved at the apical one-third, about as wide as the front metatarsi, about as long as the following joints together, the apical prolongation rather short and as wide as long, the row of spines on the inner side conspicuous and formed of about 20 black ones, on the outer side there are numerous long black hairs which do not appear on the basal half and are intermixed with some specially long and stout hairs; 2nd tarsal joint about as long as the width of metatarsi, with a deep excision near the base, haired as on the metatarsi but with only one stout hair just after the excision, two apical spines black; the 3rd tarsal joint longer than half the length of the 2nd, furnished with some black hairs on the outer side, on the inner side there is a apical black spine; two apical tarsal joints haired on the upper surface; claws simple, but the base broadened.

Wings glass-like, conspicuously irridescent, cpmparatively small, with dark veins; medial vein forked just after the base; cubital vein forked just after the middle. Halteres bright yellow.

Length of body: 2.8 mm. Length of wings: 3 mm.

Described from only one perfect female, collected by Mr. S. Kato, on the 18th of November, 1924, Taihoku, Formosa.

17. **Simulium oshimanum,** sp. nov.

Pl. II, fig. 1; Pl. XII, figs. 1-7.

Median species with the silvery-grey patch on front tibiae, the brown abdomen, the simple claws and the simple venation. Allied to *reptans*, L., but differs chiefly in the coloration and in the finer pubescence of the mesonotum; also probably allied to *eximium*, de MEIJERE.

♀. Head greyish. Frons rather narrow, shining, covered by a greyish white dust, and bordering on the eye-margin there is a few dark pubescence which is not found at the middle and becomes conspicuous on the vertex and occiput. Face somewhat oblong, shining, densely covered by a greyish white dust, and furnished with a conspicuous yellow pubescence on the whole surface but sparser at the middle. Back of the head blackish, obscured by a greyish white dust, and furnished with a yellowish pubescence which extends to the occiput, with no postocular bare rim. Proboscis pale brown, with somewhat dark paraglossa which is furnished with a conspicuous black pubescence, intermixed with a yellow one at the tip; labrum in the rest longer than the paraglossa, furnished with a very minute yellow pubescence at the apex. Palpi blackish brown with two basal joints yellowish brown obscured by a greyish dust and covered with long black hairs; 3rd joint broadest, longer than the 2nd, with the small round sensory vesicle before the middle; 4th joint narrow, slightly broadened towards the apex; apical joint long and narrow, 1½ times as long as the preceding one. Antennae orange yellow, gradually but very slightly darkened apically, obscured by a greyish dust; the first flagellar annulation longer and broader than the remaining annulations, the 5th annulation shortest, the apical annulation nearly as long as the basal one with two conspicuous but very tiny curved dark bristly hairs. Eyes with facets all practically equal.

Thorax black, obscured by a greyish dust, densely covered with a golden yellow pubescence, with 3 narrow greyish white longitudinal middle stripes and two rather broad lateral stripes which are more whitish than middle ones and are placed just above the pleurae; shoulders reddish brown, obscured by a greyish white dust; pronotum reddish, slightly obscured by a greyish dust; prothoracic episternum black, obscured by a greyish white dust; mesothoracic episternum and epimeron black, so entirely obscured by a white dust as to appear as if the pleurae had two large silvery greyish longitudinal patches. Scutellum brown, furnished with a golden yellow pubescence; postnotum brown, somewhat obscured by a greyish dust. Pleural tuft on the post parapterum yellowish.

Abdomen dark brown, with the basal and 3 apical segments shining, obscured by a greyish dust, the remaining ones velvety dark brown, furnished with a yellowish pubescence which is intermixed with long blackish hairs on the three apical segments especially at the sides; the basal scale brown, with the margin somewhat yellowish, covered with brown hairs and furnished with a fan-shaped row of yellowish hairs; the ventre paler, with the yellowish basal segments, and with the yellowish hind margins; genitalia blackish, somewhat obscured by a greyish dust, furnished with a few dark pubescence at the tip; cerci somewhat pointed at the tip.

Legs dark brown, with the front coxae, the trochanters, the tibiae more than basal half, the basal part ot femora, the basal half of the four posterior metatarsi, and the base of the 2nd joint of hind tarsi, yellowish. Front legs rather broad; femora brown with yellowish base, covered with a yellowish white pubescence which becomes blackish on where are some tiny but conspicuous dark hairs; mandible and galea yellowish. Palpi brownish black, with somewhat pale 2nd joint, furnished with conspicuous brownish hairs which become shorter and sparser towards the apical joint; 3rd joint about as long as one and a half of the following one, broadest, with a rather small sensory vesicle near the middle; 4th joint rather small, somewhat broadened at the apex; apical joint long and narrow, about twice as long as the preceding one. Antennae orange yellow to dark brown, slightly darkened towards the tip, obscured by a greyish dust, furnished with a yellowish pubescence which becomes black at the apical margin of the 2nd joint; 3rd joint longest and broadest; apical joint slightly longer than the 2nd, with one or two curved tiny yellowish hairs at the tip. Eyes with facets all practically equal.

Thorax shining black, entirely obscured by a greyish white dust, especially at the fore and lateral margins, covered with a rather dense depressed golden yellow pubescence, with no stripes. Shoulders slightly reddish-brown, obscured by a grey dust, and furnished with a few yellowish pubescence. Pronotum brown, obscured by a grey dust, and sparsely covered by dull yellowish hairs. Prothoracic and mesothoracic episterna black, obscured by a grey dust; mesothoracic and metathoracic epimera and membranous area of pleurae brown; postparapterum brown, furnished with a row of yellowish pubescence (pleural tuft). Scutellum brownish black, obscured by a greyish dust, furnished with many long blackish erect hairs at the posterior margin. Postnotum darker than the scutellum, with no hairs, but covered with a greyish dust.

Legs yellowish brown, with the fore tarsi black, and each joint darkened apically. Front legs covered with a yellowish pubescence which becomes blackish on the darker portions; femora pale at the base and the under side, furnished with dark and yellow hair at the apical half; tibiae at about $\frac{4}{5}$ basal portion quite yellow and at the remaining portion blackish, on the outerside with a distinct long silvery-grey patch at the point where the pubescence is quite white; metatarsi about $\frac{2}{3}$ times as long as the tibiae and shorter than the 4 following tarsal joints together, gradually broadened apically, slightly broader than the tibiae, the upper margin blackish, hairy, and with one conspicuous long hair; 2nd tarsal joint about $\frac{2}{3}$ times as long as the metatarsi, narrower than that, hairy as in the preceding one but with no long hair; 3rd tarsal joint about $\frac{3}{4}$ times as long as the preceding joint, narrower than that, provided with blackish hairs and one conspicuous long hair on the outer margin; 4th tarsal joint shorter than the apical one; 5th tarsal joint shorter than the 3rd. Hind legs broad and long, tarsi narrower than those of front legs; femora with the apex dark, with the base quite yellow, at the middle broadened; tibiae slightly curved, gradually broadened near the apex, with a distinct silvery-grey patch at the outerside but yellowish for about half the basal on the dark area with some long blackish hairs especially on the upper margin, the apical spine yellowish brown and conspicuous; metatarsi long and slender, slightly shorter than the tibiae, distinctly longer than the front metatarsi, slightly shorter than twice the following tarsal joints together, about $\frac{2}{3}$ basal portion yellowish, furnished with some long hairs on the upperside of the dark area, on the under margin there is a row of about 9 tiny blackish spines, the apical appendage small but conspicuous; 2nd tarsal joint slightly longer than the apical joint, with a deep excision near the base, hairy on the upper surface, with 3 distinct black apical spines; 3rd tarsal joint nearly as long as the 4th, with a long hair on the upper side, and with 2 distinct blackish apical spines; the 4th and 5th tarsal joints as in the front tarsi, with simple claws which are distinctly broadened at the base but in some specimens from Shizuoka, Kuma and Tokyo they have a trace of a tiny tooth just near the conspicuous basal broadening.

Wings hyaline, with usual veins. Halteres pale yellow. Abdomen blackish brown to brown, furnished with a very sparse yellowish pubescence, which becomes conspicuous and long on the posterior margin of the three apical segments; the 2nd, 3rd and 4th segments velvety, the remaining segments shining and obscured by a greyish dust, on the 1st segment there are two somewhat silvery-grey patches;

the basal scale blackish, with a narrow yellow margin and with a row of fan-shaped yellowish hairs at each side; ventre paler at the base; genitalia blackish, furnished with minute black hairs.

Length of body: 1.8-2.4 mm. Length of wings: 2.5-3.0 mm.

Described from 6 females collected at Kobuchisawa, Yamanashi-Prefecture (23. VII. 1921), 8 females at Anamizu, Ishikawa-Prefecture (13. VII. 1921), 8 females at Ichibu, Kumamoto-Prefecture (4. VIII. 1914), 4 females at Aoshima, Shizuoka-Prefecture (27. VI, 1. VIII, 1920), 2 females at Katsumata, Shizuoka-Prefecture (13. VI. 1920), 1 female at Tokyo (10. V. 1914), 1 female at Sasayama, Iyo, Yehime-Prefecture (21. VII. 1916), and 1 female at Ochiai, Yamaguchi-Prefecture (1. VII. 1921).

Type in the Entomological Museum of the Government Research Institute, Taihoku, Formosa.

19. **Simulium minutum,** sp. nov.

Pl. II, figs. 3 & 4; Pl. XIII, figs. 12-16.

Smallest species, with simple claws and wing-venation, very near to *5-striatum* but quite distinguished by having no yellowish pubescence on the mesonotum and by the radial vein not being entirely setose. Allied to *tuberosum*, LDST. and *argyreatum*, LDST., but at once distinguished from the former by the distinct grey face, and from the latter by having no goldish pubescence on mesonotum; also allied to *argentipes* and *fuscipilorum*, EDWARDS, and *irridescens*, de MEIJERE, but easily distinguished by the yellow antennae and by a very few black pubescence on mesonotum. This might belong to *nobile*, de MEIJERE, but mesonotum has some distinctly grey tomentose.

♀. Head shining black, obscured by a grey dust, slightly narrower than the thorax. Frons shining black, obscured by a greyish dust, near the eye-margin furnished with a very few blackish pubescence which becomes conspicuous on the vertex. Face neary quadrate, about as wide as one-fourth the width of head entirely covered with a silvery-grey dust, furnished with a few blackish pubescence which becomes conspicuous on the lower corners. Back of the head blackish, obscured by a greyish dust and sparsely covered with a few blackish pubescence which become somewhat longer and conspicuous on the occiput. Proboscis yellowish, about as long as the face; labrum yellowish brown, shining, with a few pale pubescence at the tip; paraglossa dull brown, furnished with numerous short yellowish hairs. Palpi brown with the two apical joints blackish, covered with a dense pubescence and furnished with many long blackish hairs which become shorter towards the apex and are most numerous on the 3rd joint; the 3rd joint broadest, longer than the 4th and almost twice as wide as that, with a rather small sensory vesicle near the middle; the 4th about half as long as the apical joint, with dense transverse striation; the 5th very slender and long, the striation very conspicuous. Antennae brown, with yellowish basal joints, covered with a greyish dust and a yellowish pubescence; the first joint very small, about half as long as the second, provided with some blackish hairs at the apical margin; the second joint narrower and shorter than the basal annulation of the third joint, with some blackish hairs at the apical margin; the style with yellowish 3 or 4 basal annulations, the apical annulation with one or two orange yellow bristly but minute hairs. Eyes bare from pubescence, with the facets all practically equal in size.

Thorax shining black, slightly obscured by a greyish dust, and very sparsely covered with an inconspicuous black pubescence; the shoulders very slightly brownish; pleurae brownish black, almost entirely obscured by a greyish white dust, with the wing-bases brown, almost bare from pubescence except below the wing-bases. Scutellum black, somewhat obscured by a greyish dust, provided with some blackish erect hairs on the posterior boader especially at the sides; postnotum black.

Abdomen velvet-black, with 3 apical segments shining black which are covered with a silvery grey dust, on the segment covered by the basal scale there is a silvery-grey transverse patch, the pubescence black; the basal scale brownish black, furnished with a fan-shaped row of blackish hairs; the genital part black, with somewhat blackish hairs.

Legs blackish, with front coxae and femora, trochanters, and tarsi of middle and hind legs, yellowish, obscured by a greyish dust and covered with blackish pubescence which becomes yellowish on the pale portions. The fore legs broader than the middle legs; femora yellow somewhat darkened apically, covered with a yellow pubescence; tibiae longer than the hind tibiae but narrower, straight, with a narrow and long silvery-grey patch on the outside; tarsi longer and wider than the hind tarsi, furnished with some long hairs; metatarsi broad but at the base conspicuously narrowed, slightly shorter than the hind metatarsi but conspicuously broader, about as long as the three following joints together; 2nd tarsal joint conspicuosly longer than the 2nd tarsal joint of hind legs and about twice as wide as that; 3rd tarsal joint longer than twice those of hind legs and longer than the 4th; the apical tarsal joint about as long as those of hind legs. Hind legs very stout; femora longer and wider than the tibiae, broadest at the middle, with the base yellowish, furnished with some hairs on the upper margin; tibiae strongly curved at the base where it is conspicuously narrowed, with distinct apical spines, densely covered with a silvery-grey dust especially on the upper margin of basal half. Hind tarsi somewhat longer than the femora, rather slender and long, with the apex of two first joints and the 3 apical joints dark; metatarsi long and slender, much longer than the followings together, slightly curved, furnished with more than 10 blackish minute spines along the lower margin, on the upper margin there are some long hairs; the 2nd joint longer than the 2 following ones together, with a shallow excision at the middle, furnished with 3 apical spines; the third shortest, with 2 apical spines; the 4th about half as long as the apical one; claws very simple, with the base slightly broadened.

Wings hyaline, with usual yellowish veins which are brownish at the costal area. Halteres light yellow.

Length of body: 1.2-1.8 mm. Length of wings: 1.6-2 mm.

♂. Similar to the female but darker. Head a little broader than the thorax; frons as usual, black, but covered with a silvery white dust, in the middle there is a deep longitudinal groove which extends from the upper end to the face, and on the upper border a few short black pubescence; face black, entirely covered with a silvery white tomentum and furnished with rather sparse long black hairs; vertex with a few black pubescence. Proboscis shorter than the face, blackish. Palpi blackish, furnished with black hairs. Antennae blackish brown, becoming slightly paler toward the base, covered with a brownish dust and a blackish pubescence; first joint about $\frac{2}{3}$ as long as the second; second joint broader than the basal flagellar annulation, but distinctly shorter than and about $\frac{2}{3}$ as long as the latter; the apical flagellar annulation about as long as the second annulation which is distinctly shorter than the first one, with to black apical bristles. Eyes very large as usual, the large facets extending rather below the middle.

Thorax black, with somewhat brownish shoulder, more or less shining, densely covered with a silvery white tomentum, on the anterior half there is a pair of broad velvety black (somewhat brownish) oblique bands which extend from the middle of the anterior margin to the front base of wings and are irregularly broadened at the middle; pubesence rather short and sparse, blackish brown. Scutellum black, dull coloured, nearly twice as wide as long, more or less pointed, furnished with a few very long black bristly hairs at the posterior lateral margins; postnotum brownish black, but covered with a whitish dust; pleurae dark brown, obscured by a greyish white dust, the pubescence only conspicuous below the wing-bases.

Abdomen velvet-black, with the black basal scale which is furnished with a fan-shaped row of long black hairs, covered with a very sparse short brown pubscence which becomes dense on the two basal tergites, where there is a large silvery white tomentose lateral patch; and on the 6th and 7th tergite with a distinct silvery white tomentose lateral patch. Ventre entirely covered with a greyish white dust. Genital part black, furnished with short blackish pubescence, with a pair of long flat appendages which are not pointed.

Legs blackish, with coxae and trochanters yellowish brown, and the front pair paler than the remaining pairs, covered with a greyish dust and a blackish pubescence, these become paler on the anterior legs. Front legs as in the female but rather narrow and long; tibiae with an indistinct silvery white tomentose portion. Hind legs as in the female.

Wings and halteres similar to the female.

Length of body: 1.6-1.8 mm. Length of wings: 1.9-2.2 mm.

Described from 4 females collected on the 18th of August, 1921, and 2 females and 4 males on the 8-19th of March, 1926, in Taihoku, Formosa; types in the Entomological Museum of the Government Research Institute, Taihoku, Formosa.

20. **Simulium venustum,** SAY.

Journ. Acad. Sci. Phil., III, p. 28 (1829).

Sim. piscicidium, RILEY, Amer. Ent., II, p. 367 (1870).
„ *molestum*, HARRIS, Ins. Inj. to veg., ed III., p. 601 (1862).
„ *irritatum*, LUGGER, 2nd Rept. Ent. Mim., p. 177 (1896).
„ *minutum*, LUGGER, „ „ „ „ „ „
„ *jenningsi*, MALLOCH (part), U. S. Dept. Agr. Bur. Ent., Tech. Ser. 26.
„ *rileyana*, ENDERLEIN, Konowia, I, p. 75 (1922).
„ *reptans*, IMMS (nec L.), Text Book of Entomology, p. 625 (1925).
„ *austeni*, EDWARDS, Bull. Ent. Res. VI, pt. 1, p. 33, fig. 1, 8 (1915).

Small species, with the black colouring, the silvery greyish patch on front tibiae, the radial vein not forked, and the simple claws.

♀. Head distinctly narrower than the thorax. Frons rather broad, shining black, entirely obscured by a greyish white dust, and along the eye margin furnished with a few dark erect pubescence which extends and becomes longer on the vertex and still longer on the occiput. Face about as long as wide, with somewhat triangular upper margin and inwardly curved lower margin, black but so densely covered with a greyish white dust as to produce a silvery patch, furnished with a very sparse inconspicuous pubescence. Back of the head blackish, obscured by a greyish dust and furnished with a black pubescence especially along the eye-margin where there is no postocular bare-rim. Proboscis brown, with blackish paraglossa; labrum shorter than the face; paraglossa reaching to the apex of labrum, furnished with a blackish pubescence at tip. Palpi blackish brown excepting the apex of the 3rd joint which is yellowish; the 2 basal joints wider than long, the first being longer than 2nd; 3rd joint conspicuously longer than the two basal joints together, gradually broadened towards its apex, about as long as the 4th, but thicker, covered with a greyish dust and a pale pubescence, furnished with some very long hairs, the sensory vesicle very small but with a rather large opening; 4th joint gradually broadened apically with narrower apex, the surface irregularly striated and long-haired; 5th long and slender, about 1⅓ times as long as the preceding one, conspicuously swollen at the both ends, haired as on the 4th. Antennae rather broad, dark brown, with the pedicel, the scape and the basal flagellar annulation becoming slightly palener inside; the pedicel smallest and the scape about as long as the basal flagellar annulation but distinctly narrower, the both furnished with rather conspicuous bristle-like pubescence at the upper apical area; the apical flagellar annulation longest but narrower than the preceding ones, gradually narrowed, and with somewhat pointed tip where are two minute but conspicuous curved hairs.

Thorax with three narrow somewhat distinct longitudinal grooves on the middle, median one of which is straight, the lateral ones are slightly curved outwards, and their posterior ends are roundly curved inwards and then connected with the postal end of median line, black, very slightly obscured by a white dust and yellowish depressed pubescence, the former becomes denser towards the anterior border especially on the shoulder. Pronotum somewhat brownish, obscured by a whitish dust; pleurae brownish black, obscurcd by a whitish dust excepting the membranous area, with a conspicuous silvery grey patch on posterior area of mesothoracic spiracle. Scutellum somewhat carinated in the middle of posterior portion, black, furnished with a very sparse inconspicuous pubescence; postnotum blackish, slightly obscured by a greyish dust.

Abdomen blackish, with the basal segments brownish, and the 4 apical segments shining and somewhat paler than the precedings, covered with a greyish dust and a blackish pubescence; the basal scale brown, with the margin yellowish, furnished with a fan-shaped row of pale hairs. Genital part somewhat paler than the preceding segment; ventral plate short and broad, with the trifid apical margin; cerci broad and short, with the rounded apex; lateral plates large.

Legs blackish, with the front trochanters, the front tibiae (except the apical portion), the basal half of the two hind tibiae and of the hind metatarsi, and the base of the 2nd joint of hind tarsi, yellowish. Front legs very slightly shorter than the hind legs; femora shorter than the tibiae, brownish black, covered with a yellowish pubescence, on the under surface there are some long hairs; tibiae about as long as hind femora but narrower, with a long silvery grey patch; furnished with a black pubescence which becomes whitish on the yellowish portion. Front tarsi broad, conspicuously longer than the tibiae, black; the metatarsi longer than half of the length of tibiae and about as wide as that, gradually broadened toward the apex where are some thick hairs, covered with a yellowish pubescence intermixed with conspicuous dark hairs on upper surface; the 2nd joint about $\frac{2}{5}$ times as long as the metatarsi, broad and about half as wide as long, pubescent as on the metatarsi; 3rd joint conspicuously shorter than the preceding one; about half as wide as long, hairs like those on the 2nd but shorter; the 4th joint slightly longer than wide, about half as long as the 3rd, hairy; the apical joint slender and long, about twice as long as the 4th, hairy, with rather long claws. Hind legs stout, but with the rather slender tarsi; femora conspicuously longer than the tibiae, about as long as the trochanter and the front femora together, brownish black, covered with a yellowish pubescence which becomes longer toward the apex and is intermixed with blackish hairs on under surface; tibiae about as long as the front tibiae, curved, the yellowish part does not extend to middle of the length and covered with a distinct white dust and a pale pubescence which is scattered on the whole surface and is intermixed with dark hairs on the blackish portion, the apical spines two in number distinct. Hind tarsi slightly shorter than front tarsi; metatarsi conspicuously longer than the front metatarsi but somewhat narrower, about twice as long as the remaining tarsal joints together, covered with a pale pubescence which is intermixed with long dark hairs on the lower surface, on the upper margin there is a row of about 13 short blackish spine-like hairs; 2nd joint narrow and short, longer than half the length of 2nd joint of front tarsi, with a distinct excision; 3rd joint longer than half of the length of the 2nd joint, the 4th about as long as the preceding one, both hairy; apical joint about as in the front tarsi. Claws simple, with the base distinctly swollen.

Wings quite hyaline, with yellowish veins which are simple; radial vein not folked; medial vein forked just after the base, very slightly curved; cubital vein forked at the apical portion; basal cell does not exist. Halteres pale yellow.

Length of body: 1.7–2 mm. Length of wings: 2.5–3 mm.

♂. Similar to the female but more hairy and darker. Head about as wide as the thorax. Frons very small, as usual, black, obscured by a greyish dust, in the middle there is a rather deep longitudinal groove which does not reach to the upper border. Face somewhat roundish with a slightly pointed upper margin, black, entirely covered with a silvery grey dust, and furnished with many conspicuous blackish hairs. Vertex with a few blackish erect pubescence. Back of the head furnished with conspicuous blackish pubescence which is somewhat longer than that on vertex. Palpi blackish, shorter than in the female. Antennae brownish black throughout, with a whitish dust when seen from some directions. Proboscis very short, as long as wide, with brownish labrum and blackish paraglossa. Eyes very large, as usual, with large facets which become especially large on the front central area.

Thorax black, obscured by a greyish dust and covered with a yellowish depressed pubescence which becomes conspicuous at the shoulders with a distinct transverse patch of silvery white dust just behind the shoulders, the similar but smaller patch on the brown proscutum on the broad posterior border of mesonotum so conspicuously covered with greyish white dust that it has a transverse quadrate dull greyish band along the hind margin, and furnished with some blackish hairs. Pleurae dark brown, covered with a conspicuous whitish dust excepting the membranous area and the wing-base. Scutellum velvet-black, furnished with some black erect pubescence. Postnotum with a silvery white patch which extends on the under surface of scutellum where it can be seen as a separated narrow transverse silvery patch.

Abdomen velvet black, with the blackish basal scale which is furnished with a fan-shaped row of dark brown hairs, on the 2nd segment there are the usual silvery spots just under the basal scale, furnished with numerous long blackish hairs on the basal segment, and with a very sparse black pubescence on the remaining parts. Ventre of abdomen paler especially on the base, obscured by a whitish dust. Genital part somewhat paler, obscured by a greyish dust, narrow and long, slightly curved, on the outer margin there is a row of some blackish hairs, and on the inner margin two very minute black spines at the apical corner, of which the apical one is longer than the other.

Legs blackish, slightly obscured by a greyish dust and covered with a yellowish pubescence. Front legs with black tarsi; femora covered with many long black hairs which become shorter on the basal portion; tibiae silvery white on the outside. Hind legs conspicuously broader than the front legs and slightly paler, the portions similar to the yellowish area in the female slightly recongnizable; femora provided with many long black hairs on the upper surface; tibiae broader than metatarsi, furnished with 4 distinctly long black hairs on the lower margin; tarsi broader than in the female, with 3 distinctly long black hairs on the lower margin of the metatarsi.

Wings similar to the female: halteres deep orange yellow.

Length of body: 2.5 mm. Length of wings: 2.9 mm.

Described from 2 females and 1 male collected by Dr. S. Issiki in Sachalien Island.

21. **Simulium ambiguum,** sp. nov.

Pl. III, figs 5 & 6; Pl. XIII, figs. 17-21.

Medium-sized species of blackish colour, with the striped mesonotum, no silvery greyish patch on the tibiae and the simple claws. Allied to *striatum*, BRUNETTI, distinguished by the coloration of legs.

♀. Head distinctly narrower than the thorax. Frons rather broad, blackish brown, obscured by a greyish dust but somewhat shining when seen in some directions, and along the eye-margins furnished with a few blackish pubescence which extends toward the vertex. Face more or less oblong, with the upper margin somewhat triangular and the lower margin slightly concave, brown, densely covered by a whitish grey dust and sparsely furnished with long more or less sloping darker brown hairs. Back of the head blackish, moderately obscured by a greyish dust, furnished with brownish hairs, and with a row of a few black bristly hairs just behind the eye-margin where is no distinct postocular bare rim. Proboscis brown; labrum shorter than the face; paraglossa not exceeding the labrum; mandibles darker than the labrum, reaching below the middle of the latter. Palpi dull black, more or less dusted, and black-pubescent; the 3rd joint distinctly longer than the fourth; the fifth joint hardly 1½ times as long as the 3rd joint. Antennae yellowish brown, darkened toward the tip; the scape distinctly shorter and narrower than the basal flagellar annulation; the apical flagellar annulation distinctly longer than the basal one, with two tiny apical hairs.

Thorax black, obscured by a greyish white dust and covered with a rather dense depressed brownish pubescence, in the middle there are three longitudinal blackish stripes, of which the middle one is narrow and almost reaching to the both ends, and the lateral pair is distinctly broader than the middle one but less distinct, on the outer area of this lateral stripe there is also one stripe which is similar to the latter but less distinct. Scutellum and postnotum coloured and dusted as on the mesonotum, the former furnished with long black hairs especially along the broad marginal area. Pleurae brown, entirely obscured by a greyish white dust, with the prothoracic episternum and the wing-base yellowish; pleural tuft brown.

Abdomen velvety dark brown, with the basal segment whitish, the three apical segment more or less shining and darker, and the median segments longitudinally striated as usual; pubescence blackish; the basal scale brown, with the posterior margin narrowly yellowish tinged, with a row of fan-shaped brownish hairs; genitalia dark brown, blackish pubescent.

Legs blackish, with the front coxae and trochanters, the hind trochanters, the front femora, the extreme base of the four posterior tibiae, and nearly the whole length of the four posterior metatarsi, yellowish. Front femora nearly as long as tibiae; tarsi moderately dilated, the metatarsi gradually broadened apically, very slightly shorter than the four following joints together, provided with a single very long hair near the upper tip, similar hair on the 3rd joint. Hind metatarsi rather narrow, nearly as long as the two first front tarsal joints together, with a row of about 20 tiny spine-like hairs along the lower surface, and with 3 very long hairs on the upper margin, the apical appendage moderate in size; the second tarsal joint with a distinct excision before the middle; claws long and slender, simple.

Wings with pale brownish veins; medial vein forked near the base; cubital vein forked just after the middle; halteres yellowish white.

Length of body: 2.4 mm. Length of wings: 3.1 mm.

♂. Darker and much more hairy than in the female. Head nearly as wide as thorax; frons very small as usual, black, obscured by a greyish dust, and provided with a very few blackish hairs; face oblong, with the upper end more or less pointed, and the lower margin concave, covered with a dense tomentum and furnished with rather long blackish brown hairs; vertex with a few very long blackish brown hairs; back of the head covered with a sparse yellowish pubescence but near the eye margin there is a row of sparse black hairs. Proboscis short, with the labrum very narrow, yellowish brown, blackish pubescent. Palpi blackish brown, provided with blackish hairs;

apical joint 1½ times as long as the 4th joint, conspicuously constricted after the middle, with the apex rounded; 3rd joint a little shorter than the apical one. Eyes very large as usual, the large facets occupying more than the upper-frontal ⅔. Antennae paler and broader than in the female, with the 2nd and third flagellar annulations proportionally long.

Thorax velvety black, with the brownish shoulders and the lateral borders yellowish brown, strongly rounded above, covered with a brown depressed pubescence, along the anterior margin there is a pair of silvery white transverse patches, which when seen from above do not extend over the shoulders, but when seen from side are formed of two connected patches, the front one being more or less yellowish and situated on the shoulder, and the hind one conspicuously white and placed just behind the shoulder; when seen from behind along posterior margin there is a broad silvery white transversal band, which is not seen from above, and only indistinctly from the side. Pleurae yellowish brown, obscured by a greyish dust, the middle portion being somewhat darker; the pleural tuft yellowish. Scutellum dark reddish brown, along the broad marginal area there are many long black hairs which are directed behind; postnotum dark brown, obscured by a greyish dust.

Abdomen velvety blackish brown, rather densely covered with a brown pubescence; the basal scale brown, with very long blackish fan-shaped hairs; basal segment distinctly covered with a silvery tomentum; the 4th and 5th segments with a pair of silvery white lateral patches of which the first pair is larger than the second one. Ventre brown, entirely obscured by a greyish dust, and furnished with rather few brown pubescence. Genitalia blackish, furnished with a blackish pubescence.

Legs as in the female, but more pubescent and slightly darker.

Length of body: 2.8–3.0 mm. Length of wings: 2.8–3.1 mm.

Described from one female and three males, collected by Mr. S. KATO, at Taihoku (III. 1926), Formosa. Types are preserved in the Entomological Museum of the Government Research Institute, Taihoku, Formosa.

22. **Simulium yokotense.** sp. nov.

Pl. II, fig. 5; Pl. XIII, figs. 7-11.

Brown species of middle size, with silvery-grey patch on tibiae, no stripe on mesonotum, simple claws, simple venation, and long 3rd joint of palpi. Allied to *nölleri*, FRIEDRICHS, easily distinguished by the reddish yellow femora, and the median excision of 2nd tarsal joint of hind legs; also near to *nipponense*, m., but quite distinguished from that by the position of the excision of 2nd tarsal joint of hind legs, the long third joint of palpi, the colouration, and the hairing.

♀. Head brown, obscured by a greyish dust. Frons brown, not shining, so entirely obscured by a greyish white dust as to appear white when seen from above, furnished with a whitish pubescence which becomes conspicuous and somewhat yellowish along the eye-margins, and also which becomes denser toward the vertex. Face pale brown, somewhat quadrate, more densely covered with a greyish white dust than in the frons, and furnished with a pale yellowish, nearly white, long pubescence which becomes much conspicuous at the lower margin. Back of the head blackish brown, entirely obscured by a greyish white dust and sparsely covered with a whitish pubescence which becomes somewhat longer and much conspicuous on the occiput. Proboscis about as long as the face, brown, with the yellowish labrum and the dark brown paraglossa, the former furnished with some tiny bristly hairs at the tip and the latter with a blackish pubescence especially on the apical margin. Palpi dark brown, furnished with blackish bristly hairs which are long on the 3rd joint; the two basal joints yellowish; the 3rd joint large, with a large sensory vesicle which occupies nearly the whole the basal half; the 4th joint about $\frac{5}{6}$ times as long as the 3rd, narrow; the apical joint long and slender, much shorter than twice the length of the preceding one, somewhat constricted about the middle. Antennae brown, gradually becoming yellow towards the base; the second joint longest; the 3rd joint broadest; the apical joint somewhat shorter than the second and slightly longer than the 3rd, with 3 curved apical hairs; the pubescence blackish. Eyes with the facets all practically equal in size.

Thorax blackish brown, slightly paler at the margins, obscured by a grey dust, which becomes conspicuously dense at the sides and near the fore margin, densely covered with a golden yellow depressed pubescence; proscutum, pronotum and prothoracic episternum yellowish, obscured by a dense greyish white dust, the former covered with some golden-yellow depressed pubescence, and the two latter furnished with a few whitish pubescence; mesothoracic episternum blackish, entirely obscured by a whitish dust; mesothoracic epimeron brownish, entirely obscured by a whitish dust; pleural tuft whitish; scutellum purplish brown, slightly obscured by a greyish dust, covered with a yellowish white pubescence, and provided with some long erect blackish bristly hairs along the posterior margin; postnotum black, somewhat shining, obscured by a white pubescence.

Abdomen dull brown, obscured by a greyish dust; 1st segment yellowish brown, with the narrow yellow margin, covered with yellowish dust; 2nd to 4th segments dark brown, somewhat velvety, the 5th to apical segments brownish, entirely obscured by a greyish dust, somewhat shining, covered with a yellowish pubescence intermixed with some tiny black hairs on the sides; the basal scale yellowish brown, with somewhat broad yellow margin, furnished with a fan-shaped row of yellowish hairs; genitalia blackish brown, slightly obscured by a greyish dust.

Legs dull yellow, with front tarsi blackish brown, with the apex of tibiae, almost all of femora, and four posterior coxae, brownish. Front legs rather narrow; femora brownish yellow, obscured by a greyish dust, covered with yellow pubescence, and furnished with some blackish tiny hairs on the apical portion; tibiae with a large silvery-grey patch, pale yellowish, with the extreme apex brownish black, obscured by a greyish dust, covered with a yellowish pubescence, and furnished with some erect blackish hairs; tarsi not very broad, blackish, slightly obscured by a greyish dust, covered with black, yellowish brown tipped, pubescence, with a pair of long black hairs near the apex of 1st and 3rd joints; metatarsi about as long as the following tarsal joints together, about 4.4 times as long as wide; 2nd tarsal joint about $\frac{1}{3}$ as long as the metatarsi, and about twice as long as wide; 3rd tarsal joint about $\frac{7}{10}$ times as long as ths preceding one, or about as long as the two following ones together; 4th tarsal joint about as long as the apical joint; 5th tarsal joint with simple claws. Hind legs rather broad; femora yellowish brown, with the base yellow, obscured by a greyish dust, covered with a yellowish white pubescence; tibiae strongly curved, brownish, becoming yellow towards the base, obscured by a greyish dust, covered with a yellowish white pubescence, provided with one or two long black hairs on the upper margin, with two distinct blackish apical spines, the silvery-grey patch short and narrow, and not very conspicuous; metatarsi very long and broad, but slightly narrower than in the front legs, somewhat curved, about apical one-third and lower margin blackish, the remaining part yellowish, on the upper margin there are three quite separated long black hairs which are not paired, on the lower side provided with about 11 black spines, the apical appendage rather long; 2nd tarsal joint about $\frac{1}{3}$ as long as the preceding one and about twice as long as wide, with the two apical spines black, with one somewhat long hair near the apex, the excision just in the middle; 3rd tarsal joint larger than half of the length of the 2nd, with the three apical spines black and one long hair; 4th and 5th tarsal joint as those in the front legs; claws rather narrow, with a small basal tooth.

Wings hyaline, with the pale yellowish usual veins; medial vein forked just near the base; cubital vein forked long after the middle. Halteres whitish yellow.

Length of body: 2.3 mm. Length of wings: 3.3 mm.

Described from only one, but quite complete female, collected by the author, at Yokote, Shimane-Prefecture, on the 7th of July, 1921; preserved in the Entomological Museum of the Government Research Institute, Taihoku, Formosa.

23. **Simulium nikkoense,** sp. nov.

Pl. IV, fig. 4; Pl. XIV, figs. 7-11.

This species with a large silvery patch on the tibiae of front and middle legs. Allied to *nölleri*, FRIEDRICHS (*subornatum*, EDW.), but distinguished by the several characters.

♀. Head narrower than the thorax. Frons large and quadrate with nearly straight sides, about as wide as long, slightly narrower than one-third the width of the head, not shining blackish brown and covered with numerous short depressed yellowish pubescence. Face dull coloured, slightly darker than the frons, somewhat broader than the frons, concave between the antennal fossae, furnished with a few pale pubescence. Vertex broad, shining, darker than the face, furnished with a pale pubescence. Back of the head black, covered with a pale yellowish pubescence which is longer than that on the face, without distinct postocular bare rim. Proboscis brown, longer than the frons, shorter than wide; labrum pale castaneous; paraglossa darker than the labrum and not reaching to that apex in the rest. Palpi dark brown, somewhat obscured by a greyish tomentum, furnished with pale hairs and blackish short ones, the first joint as long as the second; the 3rd conspicuously longer and thicker than the 4th, furnished with many long hairs, the sensory vesicle large and occupying more than the basal half; the 4th rather distinctly striated, covered with a few long hairs which are shorter than those on the preceding joint, at the apex there is a small sensory vesicle; the apical joint conspicuously longer than the 3rd but narrower, with numerous distinct transversal lines, and with very few long hairs which are much shorter than those on the 3rd, the basal half thicker than the remaining portion, narrowest at the apical half with a somewhat swollen apex. Antennae as usual, brownish, with the basal $\frac{1}{3}$ yellowish brown. Eyes dark castaneous, bare from pubescence, with the facets all practically equal.

Thorax blackish, obscured by a greyish dust and covered with numerous short depressed pale pubescence, without any stripes;

shoulders brown; pleurae dark brown, conspicuously palened below the wing-bases. Scutellum rather small, conspicuously pale coloured; postnotum black.

Abdomen blackish, becoming somewhat paler towards the base and the ventre, covered with a greyish dust and a yellowish white pubescence; the basal scale yellowish brown, furnished with a fan-shaped row of pale brown hairs; the ventral segments with somewhat conspicuous pale apical margin. Genital portion dark; the ventral plate somewhat triangular with a round apical margin, and furnished with a few short hairs.

Legs yellowish, with the ⅔ apical portion of femora, the ¼ apical portion of tibiae, the ⅓ apical portion of four posterior metatarsi, the 4 apical joints of four posterior tarsi, and the frontal tarsi, blackish. Fore legs longer than the hind legs, but conspicuously narrower; femora longer and conspicuously broader than the tibiae; tibiae slender and longer than the two following tarsal joints together, broadest after the middle, on the outerside of paler portion with a long large patch of silvery-grey dusting, on the black portion with many black bristly hairs which become fewer towards the inner side; tarsi slender and long, black, with no paler portion; metatarsi nearly 2½ times as long as the 2nd tarsal joint, narrowed at the base, covered with numerous black very short pubescence, furnished numerous black somewhat bristly hairs on the externo-superior side, and there is no row of spinelet; the 2nd tarsal joint 1½ times as long as the following joint, broader than the 3rd, the upper side covered with numerous hairs which are similar to those on the preceding joint but shorter; the 3rd tarsal joint shorter than the two following joints together, the hairs as those on the 2nd joint; the 4th tarsal joint very short but broader than the 3rd, covered with numerous black very short bristly hairs; the apical tarsal joint long but shorter than the 3rd, furnished with hairs which are the same as those on the preceding one. Middle legs as the hind legs, but on the tibiae there is a long large patch of silvery-grey dusting as in front tibiae. Hind legs broad and rather short; femora longer and broader than the tibiae, broadest at the middle and gradually narrowed towards both ends, furnished with a pale yellow pubescence, on the upper margin there is some dark pubescence especially towards the apex; tibiae slightly curved outwards, broadened before the apex where there are two tiny black spines on the under margin, covered with a whitish pubescence which becomes blackish and conspicuous on the black portion. The hind tarsi about as long as the front tarsi and somewhat broader than the latter; metatarsi shorter than the tibiae, longer and broader than the front metatarsi, on the blackish underside there is a row of about 20 very short black bristles and there is a process at the apex, the upper side with many pale pubescence intermixed with a few long paired hairs; 2nd tarsal joint conspicuously shorter than that of the front legs but broader, on the upper margin there is a distinct excision near the basal end and there are many hairs which are very conspicuous at the apex, and before the excision at which point they are pale yellowish, on the under margin with a few very short bristly hairs which become long and stout towards the apical margin; 3rd tarsal joint about half as long as the second, slightly narrower than it, furnished with hairs like those on the preceding one; 4th joint shortest but broader than the 3rd, with the apex yellowish, furnished with a few hairs; the apical joint narrowest, longer than the 3rd but shorter than the 2nd, furnished with similar hairs. Claws rather small, without any tooth, but roundly widened at the base.

Wings quite hyaline, with the veins pale yellow, moderate in size; medial veins forked just after the base; cubital vein forked near the middle. Halteres brownish yellow.

Length of body: 2.6 mm. Length of wings: 3.5 mm.

Described from only two females, collected by the author, at Nikko on the 3rd of July, 1911; type in the Entomological Museum of the Government Research Institute, Taihoku, Formosa.

24. **Simulium arisanum,** sp. nov.

Pl. IV, fig. 2; Pl. XIV, figs. 1-6.

Black species, allied to *nipponense*, m., but distinguished by the colouration of legs and the venation; also to *fuscipilosum*, Edw., but differs in the broad triangular frons, etc.

♀. Head black, entirely obscured by a greyish white dust. Frons slightly shining viewed from below, greyish white, furnished with a few yellowish pubescence which is not apparent at the middle or lower part. Face roundish, with the straight lower margin, black, densely covered with a greyish white dust, and furnished with a sparse yellowish pubescence which becomes slightly longer and numerous at the lower angles. Vertex somewhat shining black, entirely obscured by a greyish dust, and covered with a sparse yellowish pubescence extending on the occiput. Back of the head black, as in *nipponense*. Proboscis castaneous brown, as long as the face, with the labrum paler, with the mandible and galea darker. Palpi blackish, with the 2 basal joints somewhat paler, furnished with conspicuous blackish hairs which become sparser toward the apical joint; 3rd joint shorter than the following one and longer than twice the width, with rather small sensory vesicle near the middle; 4th joint about as wide as the preceding one, and about half as long as the following one; apical joint gradually narrowed toward the apex. Antennae dark brownish black, with the two basal joints reddish yellow, obscured by a greyish dust, and covered with numerous brownish pubescence which is nearly bare on the two basal joints but there are some conspicuous blackish hairs on the apical borders; the basal flagellar annulation longer and wider than the scape; the apical flagellar annulation longer than the others but narrower, with two curved conspicuous hairs on the tip.

Thorax dull black, obscured by a yellowish grey dust, which becomes somewhat whitish at the lateral and posterior borders, covered with a yellowish white depressed pubescence, no stripes. Proscutum somewhat reddish-brown, obscured by a grey dust, and furnished with a few yellowish white pubescence. Pronotum paler than proscutum, dusted and haired as in *nipponense*. Pleurae brownish black, with the wing-bases yellowish brown, obscured by a greyish white dust, with the pleural tuft yellowish white. Scutellum purplish black, furnished with black hairs on the posterior margin where it is somewhat paler than the rest. Postnotum as the scutellum in colour, entirely obscured by a dull yellowish grey dust, almost no pubescence.

Abdomen the 4 basal segments dull brownish black, velvety, on the remaining ones shining black but obscured by a greyish white dust, furnished with short blackish hairs which become very sparse on the velvety segment; the basal scale blackish brown, with dull brown posterior margin and with a fan-shaped row of yellowish hairs at each side; ventre slightly paler than the dorsum.

Legs brownish, with more than the basal half of all tibiae and of metatarsi of four posterior legs yellowish. Front legs covered with a yellowish white pubescence which becomes darker on the blackish portions; coxae and trochanters yellowish brown, darkened toward the apex; femora gradually darkened apically, very slightly shorter than the tibiae, the pubescence on about apical half blackish, with some long blackish brown hairs on the dorsal margin of the apical half; tibiae yellow, with the apical quarter black, with a very long silvery white patch which extends nearly to the apex from the base; metatarsi rather slender, longer than the following tarsal joints together, gradually widened toward the posterior end, furnished with numerous long blackish hairs on the outer side, and with a specially long black hair near the apex; 2nd tarsal joint shorter than one-third the length of the metatarsi, narrower than the latter, furnished with long black hairs on the outer side; 3rd tarsal joint conspicuously shoter than the 2nd and longer than the two apical joints together, furnished with long black hairs on the outer side, with a specially long black apical hair; apical joint about as long as the 4th. Hind legs longer and broader than the front legs, somewhat paler than that, covered with a blackish pubescence which becomes yellowish white on the yellowish portions; coxae blackish; trochanters brown; femora brownish black, with the base pale, conspicuously broader than the tibiae and front femora, narrowed towards the both ends, furnished with some long blackish hairs nearly throughout the surface; tibiae slightly curved, conspicuously narrowed toward the base, brownish black with the basal half pale orange yellow, furnished with some long blackish hairs on the upper magin of the apical half, with the two distinct blackish apical spines; metatarsi blackish, with about half the basal pale orange yellow, shorter and narrower than the tibiae, slightly curved twice with the distinct apical appendage which is longer than wide, on the inner side there is a row of about 15 long black spines, on the outer side there are numerous hairs which are blackish on the blackish portion and are yellowish on the yellowish portion, with three long separated black hairs; second tarsal joint about one-fifth as long as the metatarsi, furnished with blackish hairs on the outerside, with a very long black hair just after the excision which is situated near the base and is rather shallow, with the three apical spines black; 3rd tarsal joint about half as long as the 2nd and about as wide as it, black haired on the outerside, on the inner side with a black apical spine; the two apical joints as in the front legs; claws rather narrow, with a low basal process.

Wings comparatively large, with the yellowish simple veins; medial vein forked at the base; cubital vein forked near the middle. Halteres orange yellow.

Length of body: 1.8–2.0 mm, Length of wings: 3.0–3.2 mm.

Described from two females collected at Arisan, 2200 m high, on the 24th of April, 1917, by the author; type in the Entomological Museum of the Government Research Institute, Taihoku, Formosa.

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EXPLANATION OF THE PLATES.

Plate I. Enlarged

Fig. 1. ***Prosimulium kiotoense*** ♀
2. ***Prosimulium yezoense*** ♀
3. ***Eusimulium falcoe*** ♀
4. ***Stilboplàx equinum*** ♀
5. ***Eusimulium geniculare*** ♀
6. ***Eusimulium taipei*** ♀

Plate II. Enlarged

Fig. 1. ***Simulium oshimanum*** ♀
2. ***Helodon sapporoensis*** ♀
3. ***Simulium minutum*** ♂
4. ***Simulium minutum*** ♀
5. ***Simulium yokotense*** ♀
6. ***Simulium nipponense*** ♀

Plate III. Enlarged

Fig. 1. ***Simulium karenkoensis*** ♀
2. ***Stilboplax 5-striatum*** ♂
3. ***Simulium katoi*** ♀

4. *Stilboplax 5-striatum* ♀
5. *Simulium ambiguum* ♀
6. *Simulium ambiguum* ♂

Plate IV. **Enlarged**

Fig. 1. *Simulium annulipes* ♀
2. *Simulium arisanum* ♀
3. *Odagmia japonica* ♀
4. *Simulium nikkoense* ♀
5. *Odagmia oitana* ♀
6. *Odagmia bidentata* ♀

Plate V. C=Cerci; L=Lateral plate; Sg=Subgenital plate.

Prosimulium yezoense ♀

Fig. 1. Wing, ×ca 15.
2. Antenna, ×ca 49.
3. The three apical joints of palpus, ×ca 145.
4. Lateral view of anal end, ×ca 49.
5. Ventral view of anal end, ×ca 49.
6. First joint of front tarsus, ×ca 49.
7. Four apical joints of front tarsus, ×ca 49.
8. Hind tarsus, ×ca 49.
9. Hind claw, ×ca 145.

Plate VI. L=Lateral plate; C=Cerci; Sg-Subgenital plate.

Prosimulium kiotoense ♀

Fig. 1. Wing, ×ca 15.
2. Antenna, ×ca 49.
3. Palpus, ×ca 145.
4. Lateral view of anal part, ×ca 49.
5. Ventral view of anal part, ×ca 49.
6. First joint of front tarsus, ×ca 49.
7. Four apical joints of front tarsus, ×ca 49.
8. Hind tarsus, ×ca 49.
9. Hind claws, ×ca 145.

Plate VII. C=Cerci; L=Lateral plate; Sg=Subgenital plate.

Helodon sapporoensis ♀

Fig. 1. Hind tarsus, ×ca 49.
2. Front tarsus, ×ca 49.
3. Hind claws ×ca 145.
4. Palpus ×ca 145.
5. Anal end ×ca 49.
6. Antenna ×ca 49.
7. Wing ×ca 15.

Simulium katoi ♀

8. Antenna, ×ca. 49.
9. Hind tarsus, ×ca 49.
10. Front tarsus, ×ca 49.
11. Hind claw, ×ca 145.

Plate VIII.

Eusimulium geniculare ♀

Fig. 1. Wing, ×ca 15.
2. Three apical joints of palpus, ×ca 145.
2. Antenna, ×ca 49.
4. Hind tarsus, ×ca 49.
5. Intermediate tarsus, ×ca 49.
6. Front tarsus, ×ca 39.
7. Hind claw, ×ca 145.

Eusimulium bonninense ♀

8. Wing, ×ca 15.
9. Antenna, ×ca 49.
10. Front tarsus, ×ca 49.
11. Hind tarsus, ×ca 49.
12. Front claw, ×ca 145.

Eusimulium taipei ♀

13. Antenna, ×ca 49.
14. Three apical joints of palpus, ×ca 145.
15. Wing, ×ca 15.
16. Front tarsus, ×ca 49.
17. Hind tarsus, ×ca 49.
18. Hind claw, ×ca 145.

Plate IX.

Eusimulium falcoe ♀

Fig. 1. Wing, ×ca 15.
2. Antenna, ×ca 49.
3. Front tarsus, ×ca 49.
4. Hind tarsus, ×ca 49.
5. Hind claw, ×ca 145.

Odagmia karenkoensis ♀

6. Three apical joints of palpus, ×ca 145.
7. Antenna, ×ca 49.
8. Front tarsus, ×ca 49.
9· Hind tarsus, ×ca 49.
10. Hind claw, ×ca 145.

Odagmia bidentata ♀

11. Hind tarsus, ×ca 49.

Plate X. C=Cerci; Sg=Subgenital plate.

Stilboplax 5-striatum

Fig. 1. Wing (♀), ×ca 15.
2. Palpus (♀), ×ca 149.
3. Antenna (♀), ca 49.
4. Antenna (♂), ×ca 49.
5. Front tarsus (♀), ×ca 49.
6. Hind tarsus (♀), ×ca 49.
7. Hind claw (♂), ×ca 145.
8. Hind claw (♀), ×ca 145.
9. Anal end (♂), ×ca 145.

Odgamia bidentata ♀

10. Three apical joints of palpus, ×ca 145.
11. Front tarsus, ×ca 49.
12. Wing, ×ca 15.
13. Hind claw, ×ca 145.

Plate XI. C=Cerci; L=Lateral plate; Sg=Subgenital plate.

Odagmia japonica ♀

Fig. 1. Wing, ×ca 15.
2. Three apical joints of palpus, ×ca 145.
3. Hind leg, ×ca 49.
4. Front tarsus, ×ca 49.
5. Hind claw, ×ca 145.

Odagmia iwatensis ♀

6. Three apical joints of palpus, ×ca 145.
7. Front tarsus, ×ca 49.
8. Hind tarsus, ×ca 49.
9. Hind claw, ×ca 145.

Odagmia oitana ♀

10. Wing, ×ca 15.
11. Antenna, ×ca 49.
12. Front tarsus, ×ca 49.
13. Hind tarsus, ×ca 49.
14. Hind claw, ×ca 145.
15. Anal part of abdomen, ×ca 49.

Plate XII.

Simulium oshimanum ♀

Fig. 1. Wing ×ca 15.
2. Three apical joints of palpus, ×ca 145.
3. Antenna, ×ca 49.
4. Front tarsus, ×ca 49.
5. Hind tarsus, ×ca 49.
6. Hind claw, ×ca 145.
7. Anal end, ×ca 49.

Simulium annulipes ♀

8. Wing, ×ca 15.
9. Third and fourth joints of palpus, ×ca 145.
10. Fifth joint of palpus, ×ca 145.
11. Antenna, ×ca 49.
12. Front tarsus, ×ca 49.
13. Hind tarsus, ×ca 49.
14. Hind claw, ×ca 145.

Simulium katoi ♀

15. Third and fourth joints of palpus, ×ca 145.
16. Fifth joint of palpus, ×ca 145.

Pate XIII.

Simulium nipponense ♀

Fig. 1. Wing, ×ca 15.
2. Hind tarsus, ×ca 49.

3. Hind claw, ×ca 145.
4. Three apical joints of palpus, ×ca 145.
5. Front tarsus, ×ca 49.
6. Antenna, ×ca 49.

Simulium yokotense ♀

7. Three apical joints of palpus, ×ca 145.
8. Hind claw, ×ca 145.
9. Hind tarsus, ×ca 49.
10. Front tarsus, ×ca 49.
11. Antenna, ×ca 49.

Simulium minutum

12. Wing (♀), ×ca 15.
13. Three apical joints of palpus (♀), ×ca 145.
14. Hind tarsus (♀), ×ca 49.
15. Front tarsus (♀), ×ca 49.
16. Hind claw (♀), ×ca 145.

Simulium ambiguum

17. Three apical joints of palpus (♀), ×ca. 145.
18. Antenna (♀), ×ca 49.
19. Front tarsus (♀), ×ca 49.
20. Hind tarsus (♀), ×ca 49.
21. Hind claw (♀), ×ca 145.

Plate XIV.

Simulium arisanum ♀

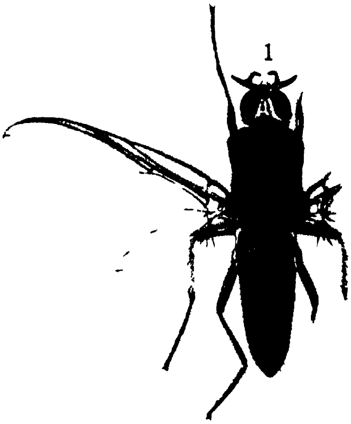
'Fig. 1. Wing, ×ca 15.
2. Three apical joints of palpus, ×ca 145.
3. Antenna, ×ca 49.
4. Front tarsus, ×ca 49.
5. Hind tarsus, ×ca 49.
6. Hind claw, ×ca 145.

Simulium nikkoense ♀

7. Front tarsus, ×ca 49.
8. Hind tarsus, ×ca 49.
9. Hind claw, ×ca 145.
10. Wing, ×ca 15.
11. Palpus, ×ca 145.

Odagmia oitana ♀

12. Palpus, ×ca 145.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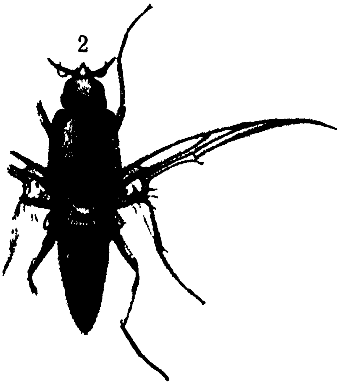
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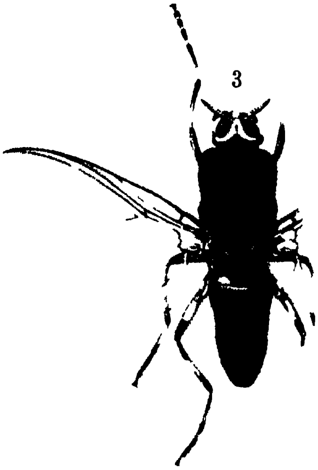
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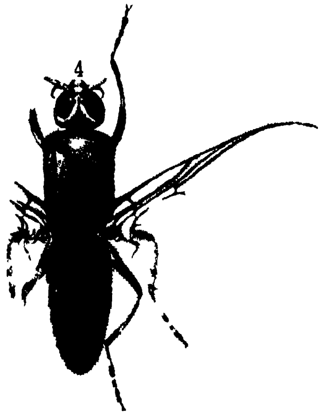
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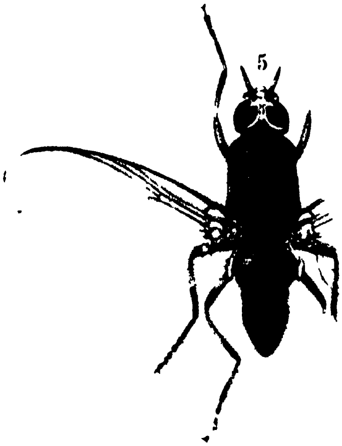
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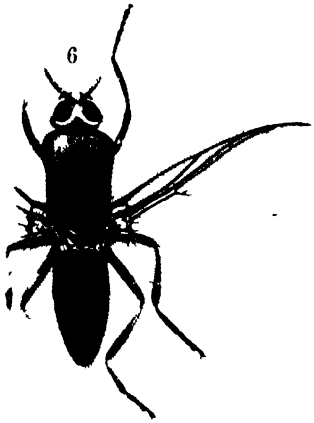
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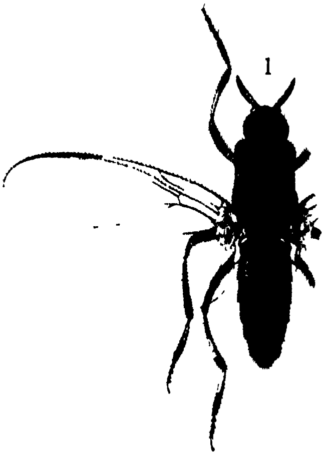

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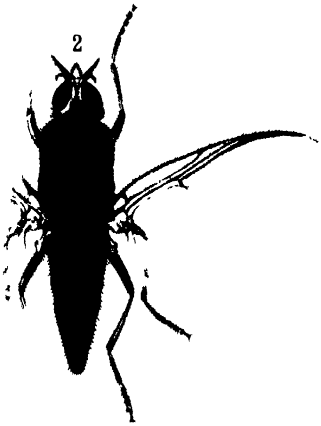

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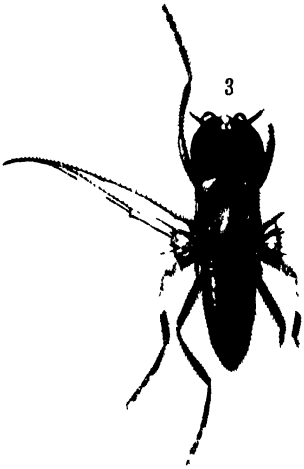

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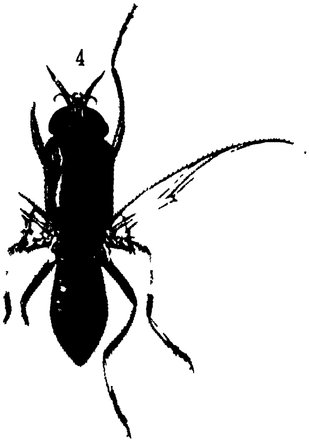

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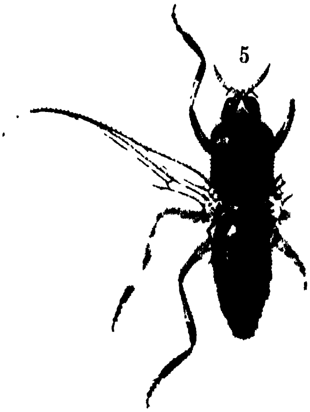

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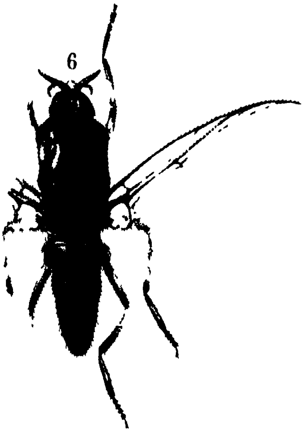

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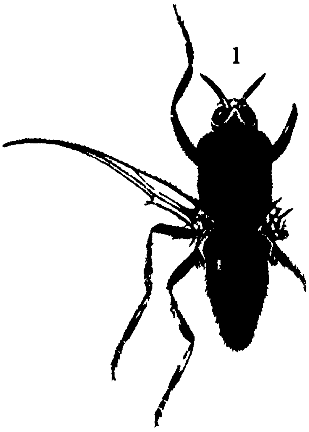

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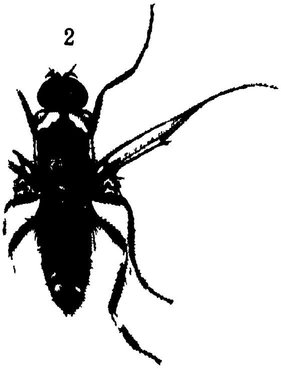

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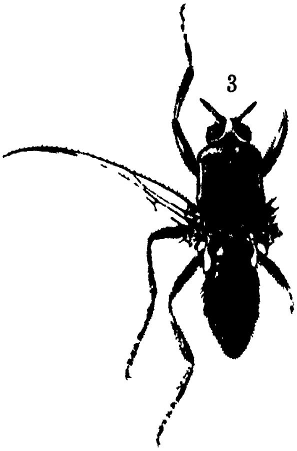

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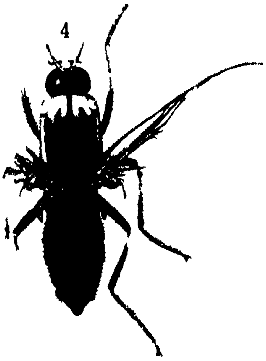

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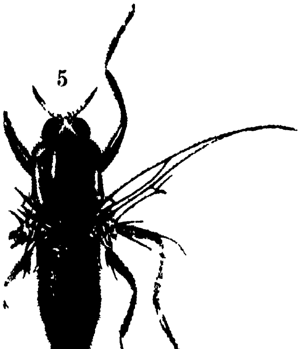

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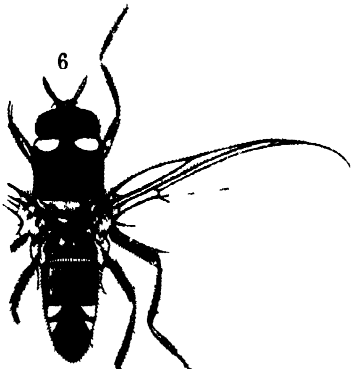

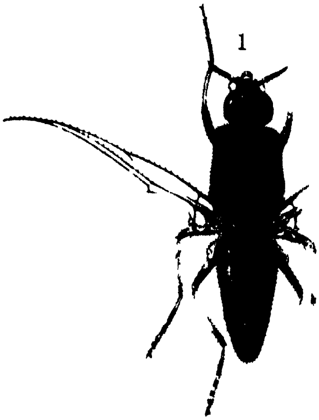
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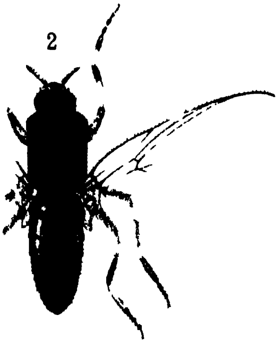
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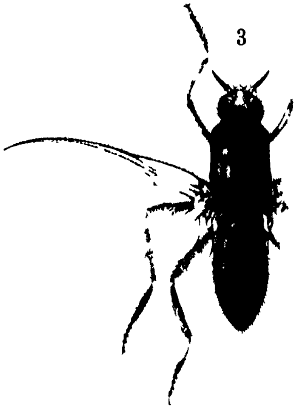
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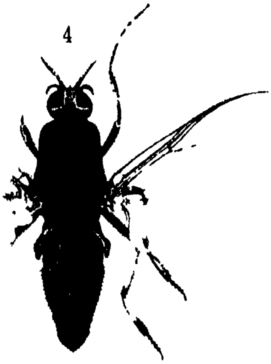
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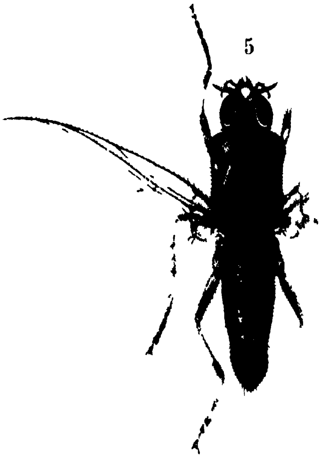
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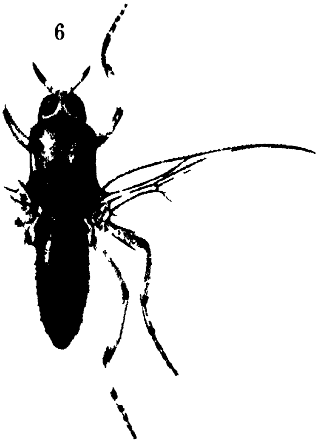
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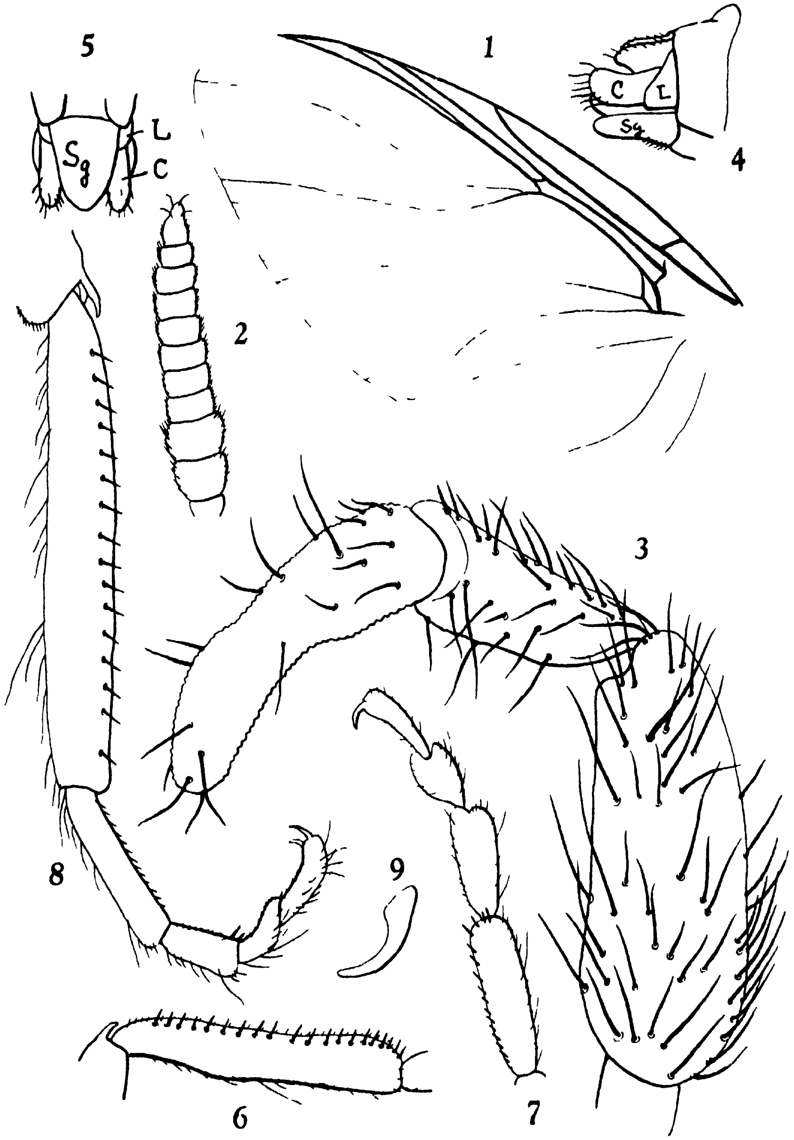
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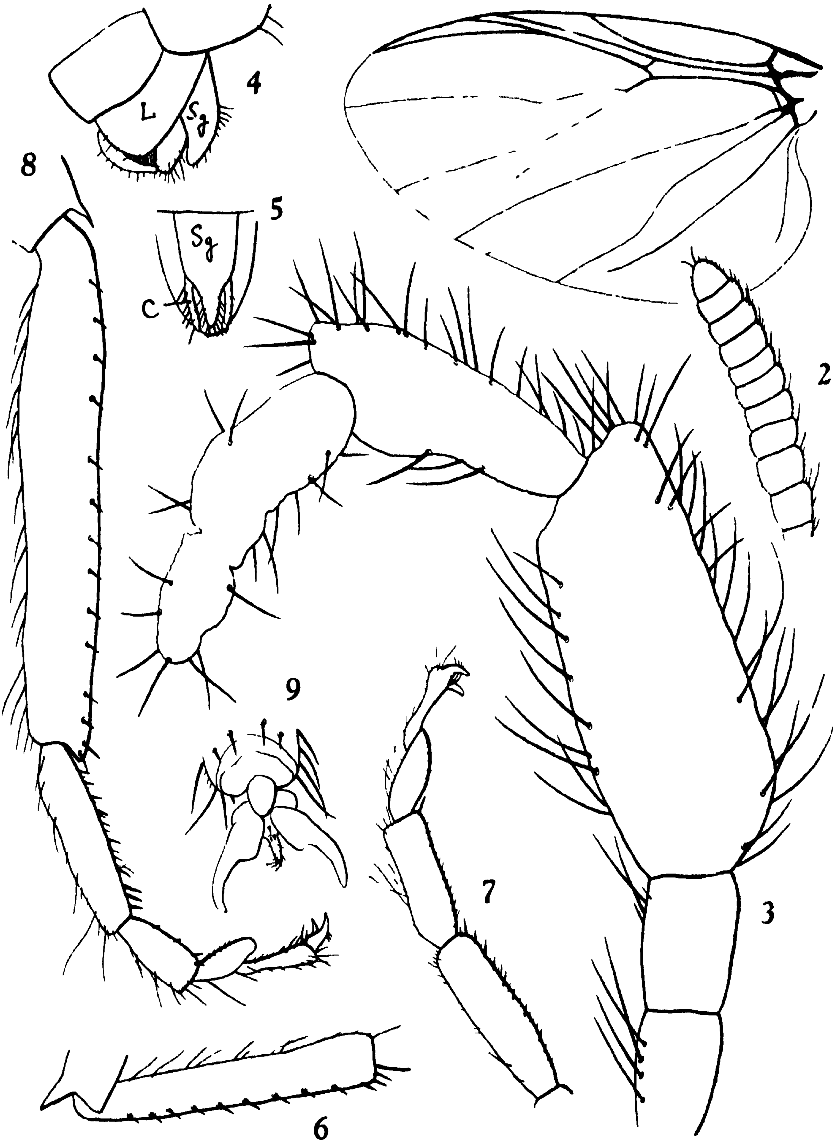
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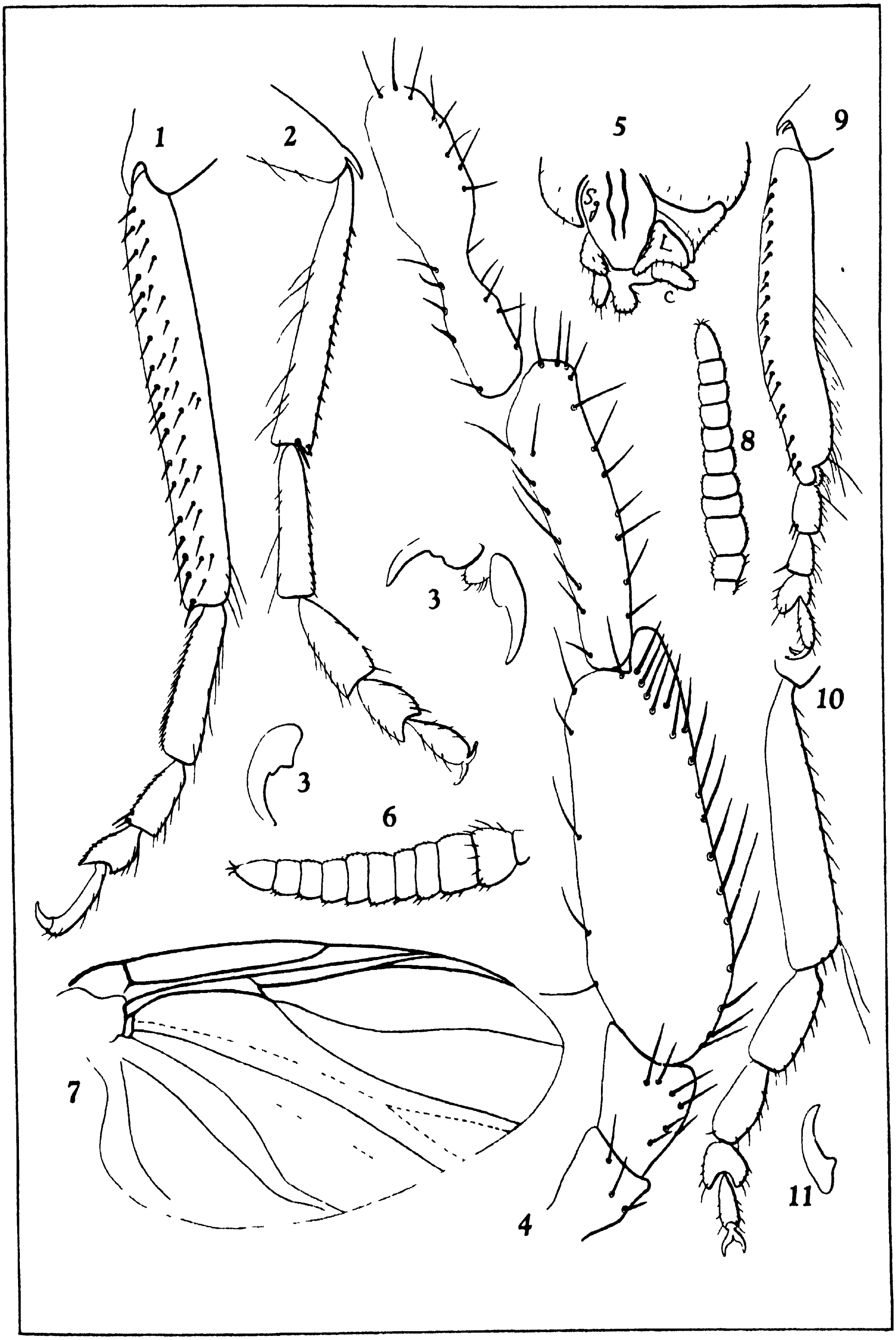
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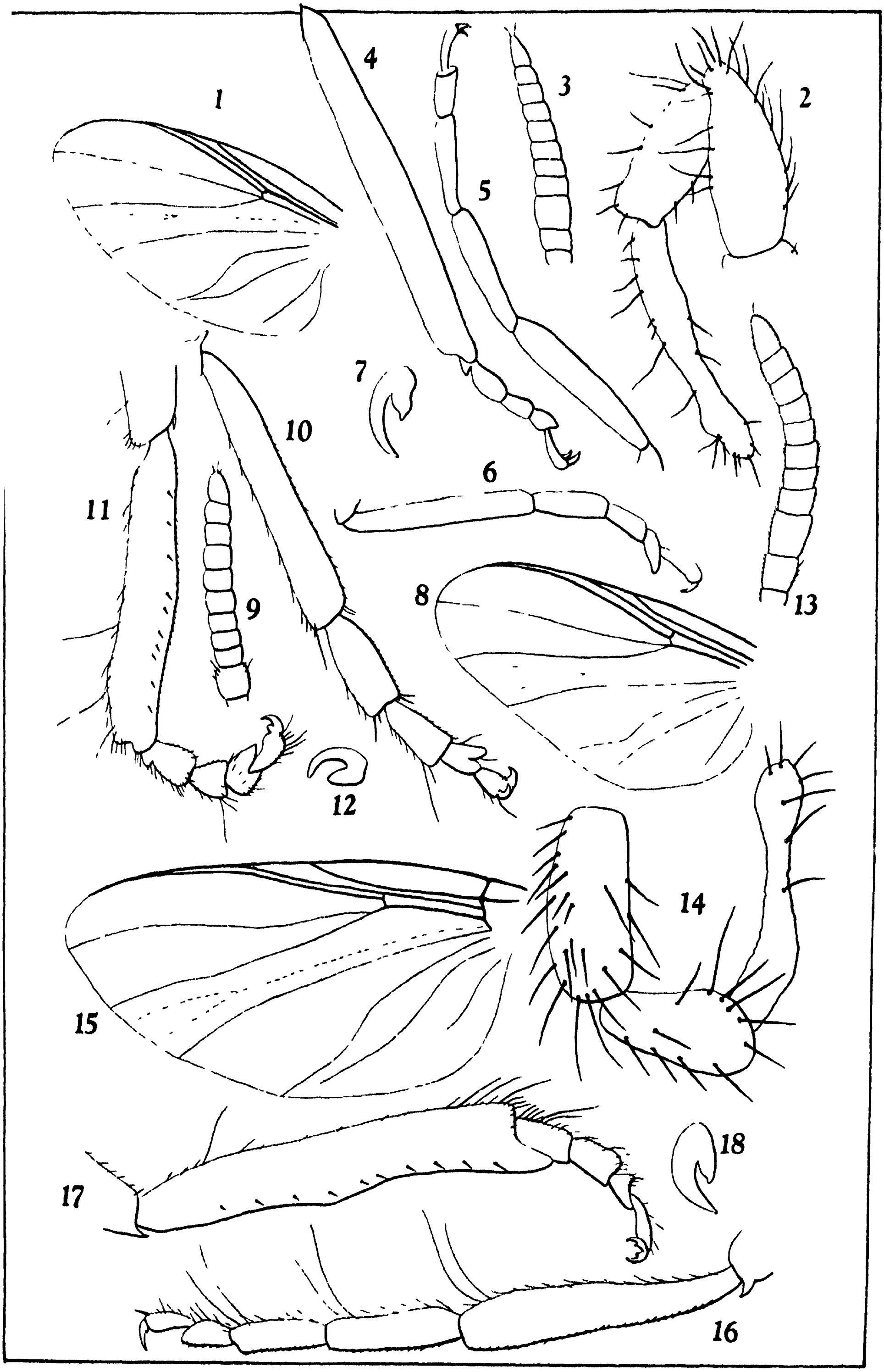

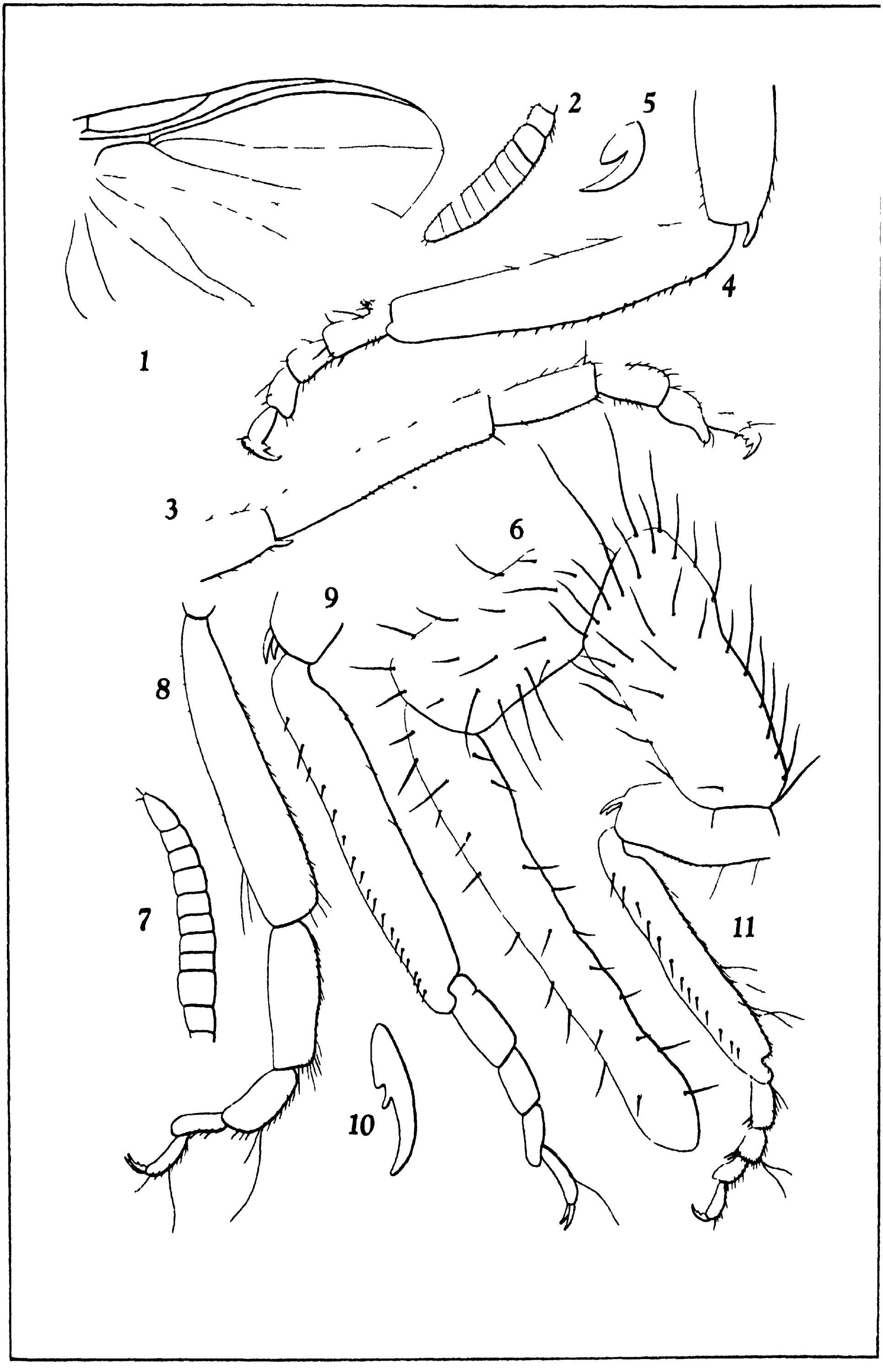

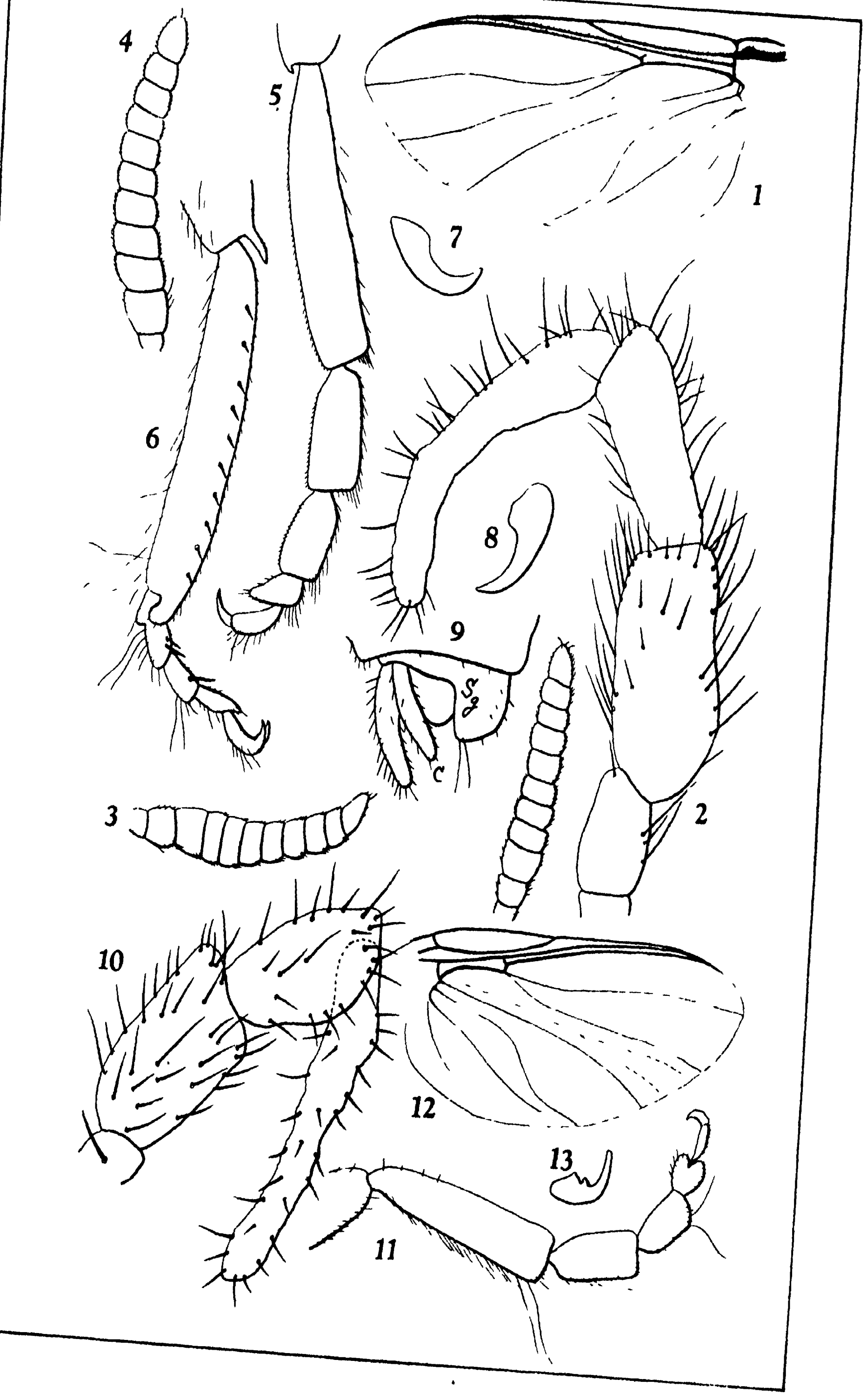
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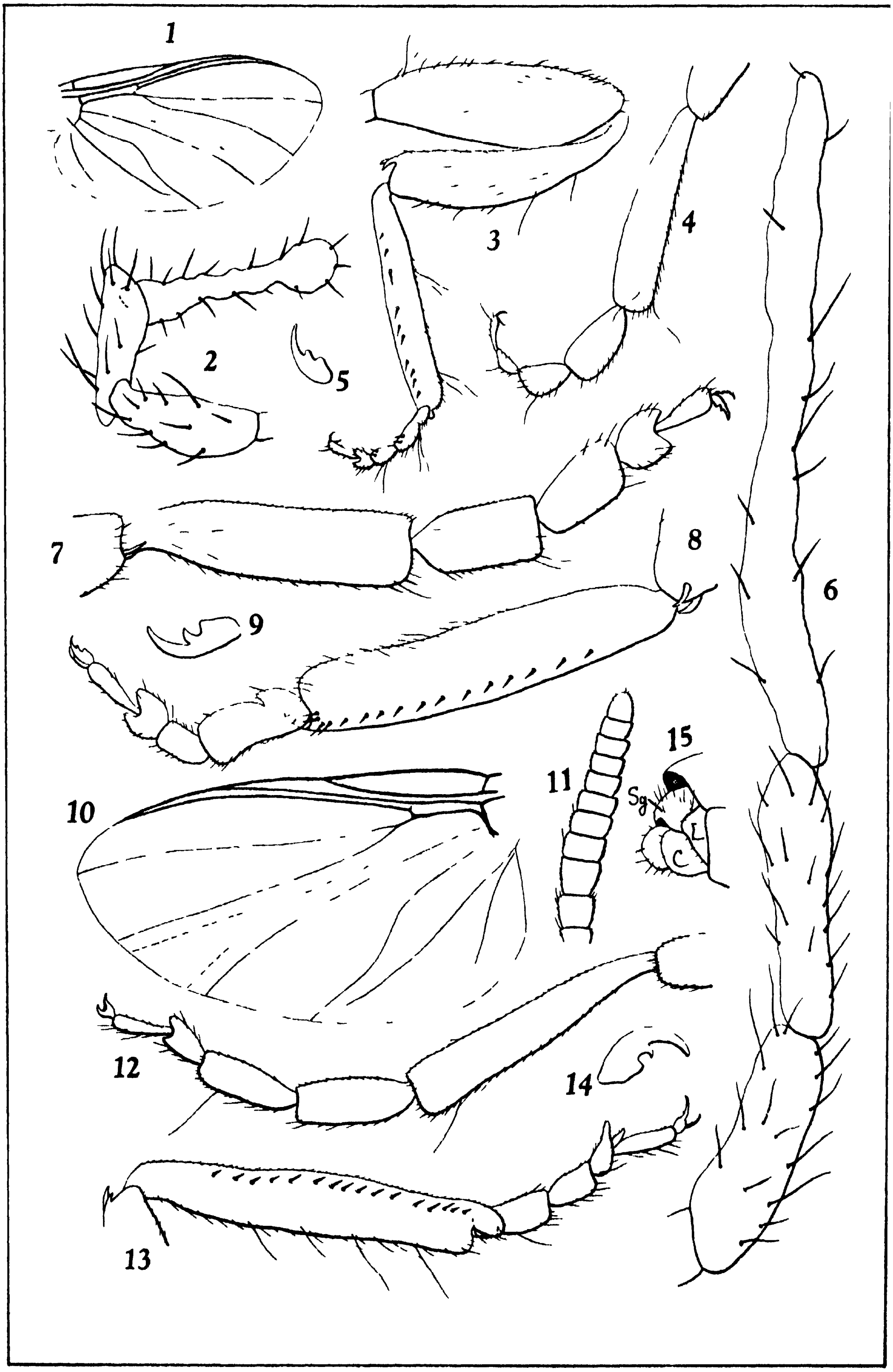
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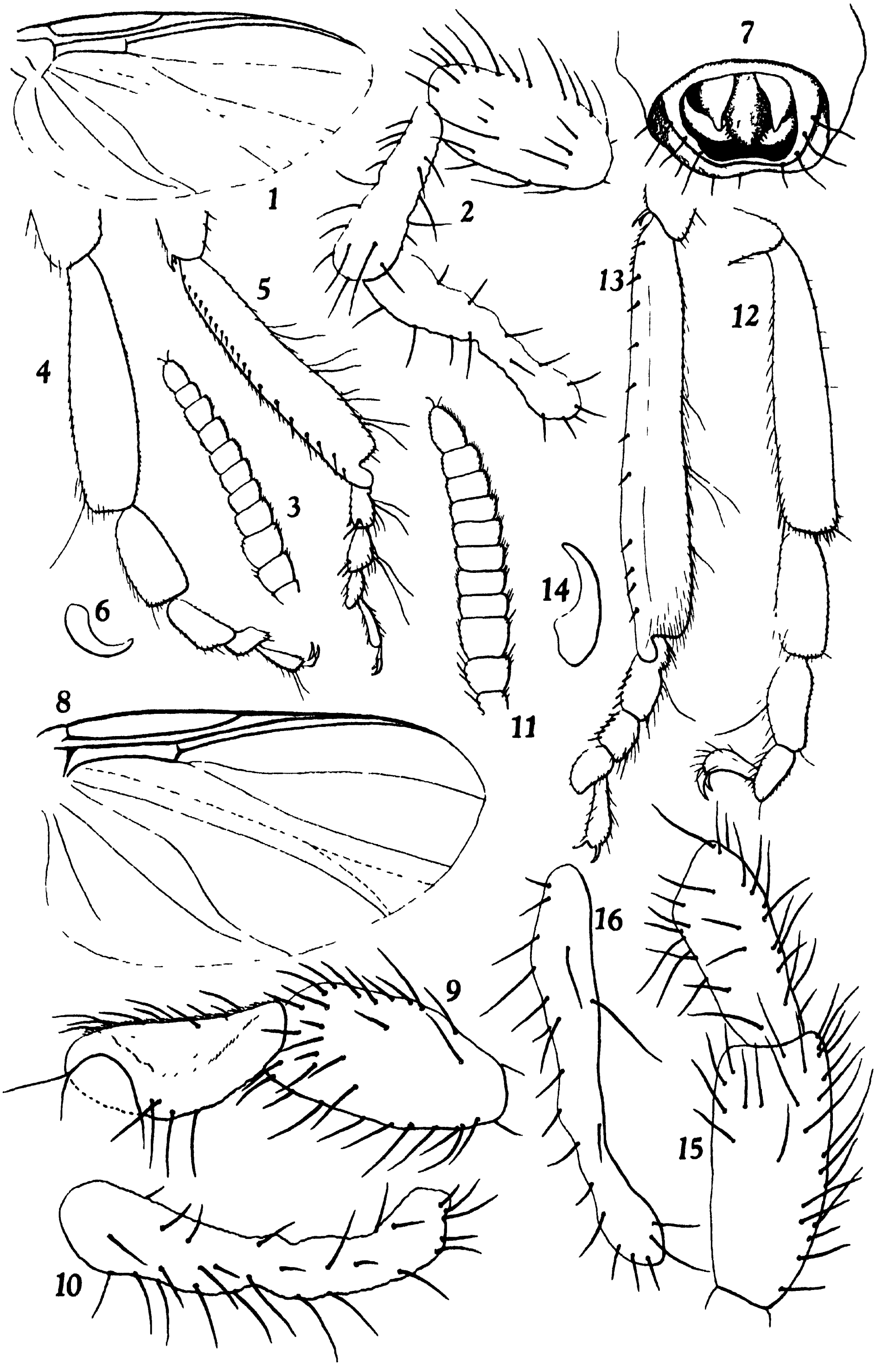

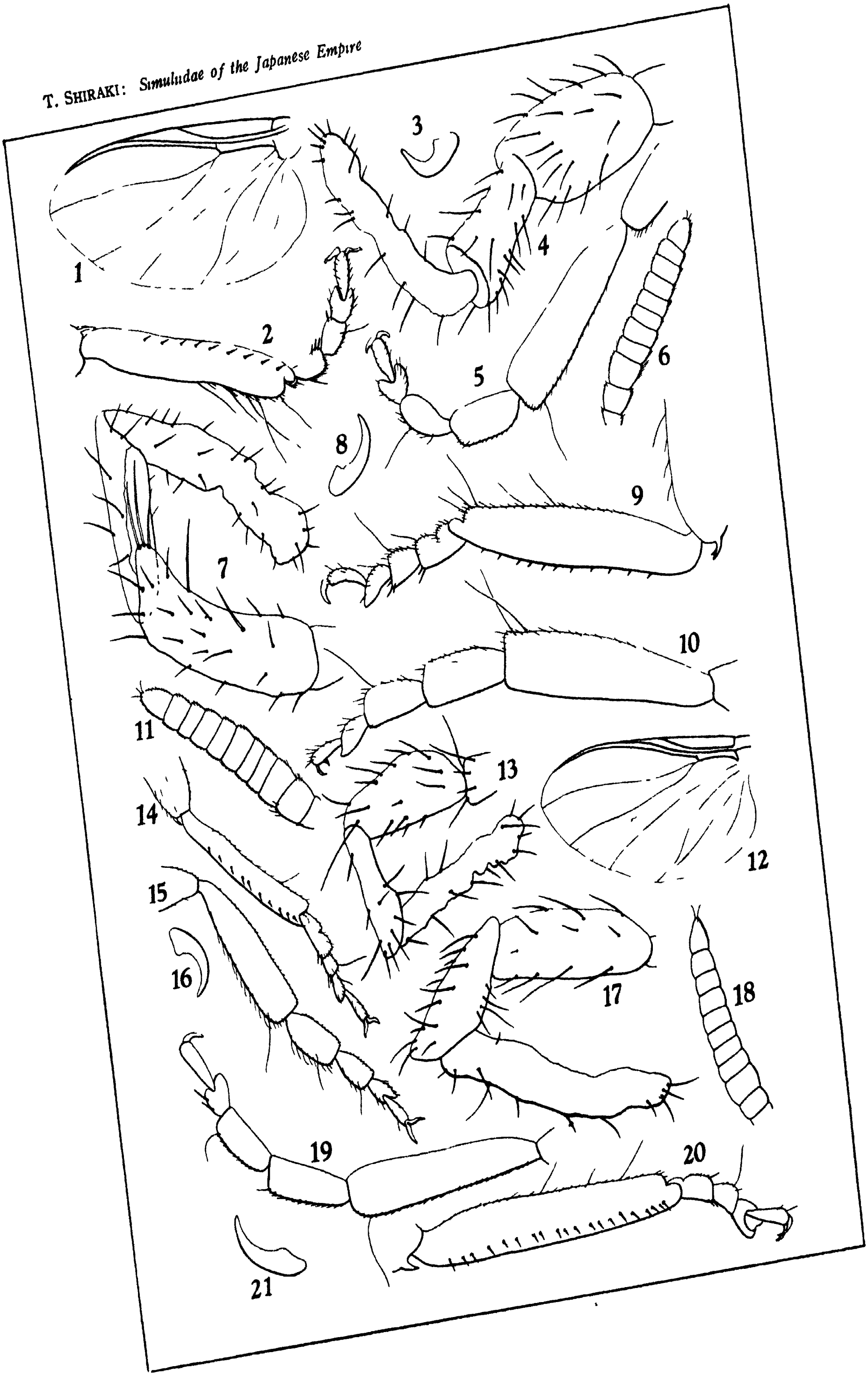

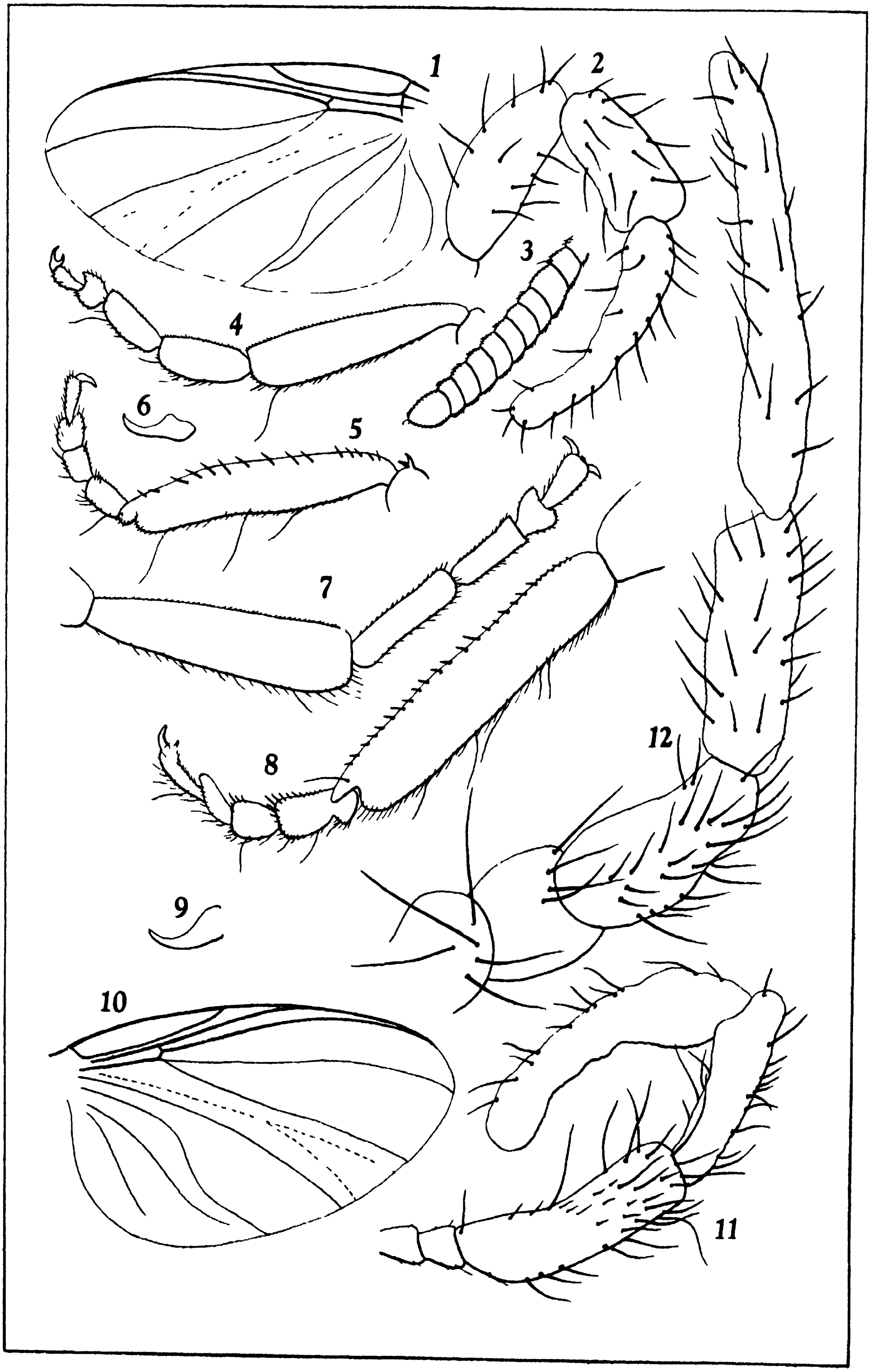

Studies on the Supercooling Death of Insects

Kikuô SHIBATA

(Accepted for publication, June 6, 1935)

I. Introduction

It has been generally believed that insects exposed to low temperatures below freezing point of their body fluides freeze to deaths. This general belief depends upon the assumption that the cold-death of insect is caused simply by the freezing of the body fluid. Concerning cold-death we have at present many experimental studies (see BACHMETJEW, PAYNE, ROBINSON etc.).

In the course of a study on the cold-death of a fruit fly, *Chaetodacus cucurbitae* COQUILLETT, however, I found another cause of cold-death which is quite different from the so called freezing death. When the insect is exposed to low temperatures which lie below the freezing temperature, it is killed, even if the body fluid is never brought to freeze. That is, when the state of supercooling continues for a certain time, cold-death occurs in this insect.

This paper deals with the result of my experimental work on the cold-death of the fruit fly, from which a conclusion is formed that there are two causes in the cold-death of insects, namely freezing death, and supercooling death.

The writer wishes to express his gratitude to Prof. T. SHIRAKI and Prof. K. KOIDSUMI for having suggested the problem, especially to the latter for his helpful criticism.

[Mem. of the Fac. of Sci. and Agr., Taihoku Imp. Univ. Formosa, Vol. XVI, No. 2-a, August, 1935.]

II. Material and Methods

Matured larvae (3rd instar) of a fruit fly, *Chaetodacus cucurbitae* COQUILLETT, were used in this experiment. They are important noxious insects and work great injury to a great number of cucurbitaceous fruits in our Formosa. The eggs are laid under the cuticle of the fruits, and the larvae hatched from them are voracious feeders, which when they have attained full growth leave the fruit and enter the soil, where they change into pupae.

Before the experiment the larvae were carefully washed with fresh water, and the water which stuck to the body surface was wiped off with blotting-paper.

One of the principal things in this experiment is to keep the larvae in the supercooled state for a long time at a lower temperature than the freezing temperature of the body fluid, and another is to produce ice crystals rapidly in the insect body. The former may be attained by a slow rate of cooling in the still and undisturbed state of the animal, the latter, on the contrary, may be easily brought by breaking the supercooled state of the animal with a little mechanical shock.

The detailed procedure is as follows. A large PETRI's glass dish hung by an elastic rubber band was placed in a low temperature air thermostat, and a small dish containing experimental animals without lid was put in the large dish. These two dishes were separated from each other by cotton in order to check the mechanical disturbance of the small dish coming from outside. Thus I was able to cool the larvae without forming ice crystals in the body. In order to make the insect freeze, on the other hand, I gave mechanical shockes at the rate of 60 per minute to a lidless dish, in which the larvae were placed, by means of a little motor prepared specially in the low temperature thermostat.

The larvae employed for the experiment were collected in a single infested fruit and divided into two parts, one part for each purpose.

The determine whether the larvae froze or not we used a dull needle; unfrozen larvae, namely those of supercooled are soft, but the larvae completely frozen or those in early stage of freezing are hard. The larvae taken out of the thermostat were reared on normal food fruit. After 24 hours from the time of taking out of thermostat the larvae were examined to determine whether they were dead or still living. The writer recorded the larvae moving actively as living and those completely inactive as dead.

III. Results of Experiments

A. Exposure to -3.4°C

The larvae were exposed to -3.4°C, which had been proved by a preliminary experiment to be lower than the freezing temperature of this insect. The numbers of frozen and unfrozen larvae in the quiescent state or by giving the mechanical disturbance obtained from the various time of exposure to this low temperature are as follows.

TABLE I.

Temperature of Experiment -3.4°C

Date of Experiment 27—I— 1934 Air Temperature 19°C

Time of exposure to low temp.	Results of experiment with mechanical shocks					Results of experiment in quiescent state				
	Total number of tested	Frozen larvae		Supercooled larvae		Total number of tested	Frozen larvae		Supercooled larvae	
		Number	Survival number	Number	Survival number		Number	Survival number	Number	Survival number
mins. 5						47	0		47	47
10	23	5	3	18	18	43	0		43	43
15	24	9	1	15	15	36	0		36	36
20	23	20	1	3	3	35	5	2	30	30
25	36	36	0	0		33	6	1	27	27
30	34	34	0	0		24	4	0	20	20
35	31	31	0	0		47	3	0	44	44
40						36	5	0	31	31
1 hrs.						31	3	0	28	19
2						20	7	0	13	13

Time of exposure to low temp.	Results of experiment with mechanical shocks					Results of experiment in quiescent state				
	Total number of tested	Frozen larvae		Supercooled larvae		Total number of tested	Frozen larvae		Supercooled larvae	
		Number	Survival number	Number	Survival number		Number	Survival number	Number	Survival number
4 hrs.						20	6	0	14	7
6						29	9	0	20	2
10						27	4	0	23	3
16						41	5	0	36	1
24						40	13	0	27	0
36						48	17	0	31	0
48						37	11	0	26	0
60						31	14	0	17	0
72						32	19	0	13	0
120						30	16	0	14	0

All the materials given the mechanical shocks froze after 25 minutes. The discussion presented by ROBINSON intended to show that the bound water which is combined with the colloid particles of the protoplasm will be set free by the mechanical disturbance, but as a result of repeated experiments of freezing point of body fluid with the thermoelectric method I found no difference between the freezing temperature of the insects kept in still state and those given the mechanical shocks.

In the case of insects kept in the still state the number of frozen materials increased after 20 minutes exposure, only 50% of the total number froze even if exposed for 120 hours. Most frozen larvae could never survive after being exposured to low temperatures, but a few larvae frozen survived after melting of the ice formed in the body. This reason will be mentioned in the next paper.

As through an experiment to determine the rate of cooling with the thermoelectric method, it was proved that the insect body must be cooled to the zone of supercooling for more than 5 minutes it is obvious that all the unfrozen larvae shown in the table were in supercooling state. The unfrozen larvae exposed for only a short time, such as less than 40 minutes, to low temperatures survived completely. But in the case of long exposure the death occured even though in unfrozen state, i. e. the number of dead larvae increased with hours of exposure after 2 hours and all died after 16 hours of exposure.

B. Exposure to -5°C

The results obtained from the exposure to -5°C were tabulated in the following table.

TABLE II.

Temperature of Experiment -5°C

Date of Experiment 23—I—1934 Air Temperature 14°C

Time of exposure to low temp.	Results of experiment with mechanical shocks					Results of experiment in quiescent state				
	Total number of tested	Frozen larvae		Supercooled larvae		Total number of tested	Frozen larvae		Supercooled larvae	
		Number	Survival number	Number	Survival number		Number	Survival number	Number	Survival number
mins. 2	35	0		35	35	28	0		28	28
5	25	4	2	21	21	16	0		16	16
10	33	21	5	12	12	25	0		25	25
15	37	37	2	0		43	0		43	43
20	32	32	0	0		19	0		19	19
30	45	45	0	0		27	1	0	26	26
1 hr.	29	29	0	0		31	0		31	29
2	30	30	0	0		28	0		28	24
3						37	4	0	33	19
4						44	1	0	43	10
5						49	0		49	12
6						40	4	0	36	3
8						50	3	0	47	0
10						42	6	0	36	0
24						35	11	0	24	0
48						33	14	0	19	0
60						36	20	0	16	0

The larvae given the mechanical shocks froze within 15 minutes, while of those kept in still state only 60% of the total number to froze after even 60 hours, the remainder were left in unfrozen state and died after 8 hours exposure.

C. Exposure to -12°C

The larvae were exposed to a constant low temperature of -12°C with the same method as mentioned in experiments A and B. The results of this experiment is as follows.

TABLE III.

Temperature of Experiment -12°C

Date of Experiment 13—II—1934 Air Temperature 21°C

Time of exposure to low temp.	Results of experiment with mechanical shocks					Results of experiment in quiescent state				
	Total number tested	Frozen larvae		Supercooled larvae		Total number tested	Frozen larvae		Supercooled larvae	
		Number	Survival number	Number	Survival number		Number	Survival number	Number	Survival number
mins. 2	30	18	13	12	12	42			42	42
4	39	39	1	0		39			39	39
6	32	32	0	0		24			24	24
10	28	28	0	0		41	8	1	33	32
20	41	41	0	0		32	4	0	28	22
40	17	17	0	0		36	6	0	30	17
1 hr.						35	10	0	25	10
1.5						41	4	0	37	4
2						51	9	0	42	0
2.5						33	12	0	21	0
3						35	17	0	18	0
4						33	19	0	14	0
8						29	23	0	6	0
24						38	31	0	7	0
48						34	29	0	5	0
60						37	34	0	3	0

The results shown in the above table indicate that after 6 minutes exposure all the larvae given the mechanical shocks froze but none of those kept in still state did so. The number of frozen larvae in the latter condition, however, increased with the time of exposure, that is, after exposure of 2 hours 90% of the total number froze and 10% remained in the unfrozen supercooling state, but finally died completely.

D. Minimum Time of Exposure Necessary to kill 100% of the Tested

In order to show the important results obtained in the 3 series of experiments described above I bring a schedule which indicates the minimum duration of exposure required to kill 100% of the tested whether from freezing or from supercooling.

TABLE IV.

Temperature of exposure	Minimum time, for killing 100% of the larvae in frozen state	Minimum time, for killing 100% of the larvae in supercooled state
−3.4 °C	25 mins.	16 hrs.
−5.0	20	8
−12.0	6	2

As clearly shown in the table above, the minimum time required for killing 100% of the tested larvae becomes shorter when the temperature of the exposure is lower, whether the cause of the death may be freezing or supercooling. According to NEWTON's famous law of cooling, the greater the rate of cooling of a material, the greater is the difference between the temperature of surroundings to which the material is exposed and that of the material before exposure. It is therefore obvious that the minimum time necessary for killing all the tested larvae as a result of freezing shortens according to the lowness of the exposing temperature, for the lower the temperature of exposure, the more rapid is the time of freezing.

As for the reason why the same relation is held in the death of supercooling, I can not say at present.

Then, it is also to be noted from the table that in every case the time necessary to kill 100% of the materials is far longer in the supercooling death than in the freezing death.

E. Condition of Supercooling

It is a long known fact that both the depth and the duration of the supercooling of the liquid depend considerably upon the condition of the fluid during the course of cooling. For instance even in the case of the simple solute such as water, DESPRETZ-MONTI made it cool until -7°C; GRAY-LUSSAC, made water float on oil until -12°C; DESPRETZ, kept water in a glass tube of a thermometer until -20°C. The depth and the duration of supercooling was also effected by from the rate of cooling. It was my frequent experience also that from the rate of cooling or the condition of the larvae there resulted a fairly remarkable variation of both the depth and the duration of the supercooling.

We are of course unable to discuss completely in the same manner the supercooling of the insect body as that of the simpler case of water. But it would not be to much to say that at least the presence of shocks or the rate of cooling, have also a close relation to the depth and the duration of the supercooling of the insect body. For instance a kind of *Heteroptera*, *Perillis bioculatus*, was cooled until -26°C by KNIGHT and a beetle which lives in the wood of the oak tree was cooled until -22°C by PAYNE in unfrozen state. These supercooling points are no doubt below the eutetic point of NaCl which consititutes more than 80% of soluble substances contained in the body fluid of insects (SACHAROV, 1930). Thus we are able to obtain various points of supercooling by suitable methods.

The long duration of the supercooled state may most easily be attained by slowing the rate of cooling. I have an experiment which proved this relation. The larvae were divided into three parts; one part was put in a glass dish without a lid; the second part was placed in a similar dish having a lid; The third part was packed with absorbent cotton to prevent the conduction of heat. By exposing these three parts to the same low temperature, we may obtain three cooling rates. The rate of cooling of the larvae kept in the dish without a lid is the greatest; that of the larvae packed with cotton is the slowest; and that in the dish with a lid lies between these two. The results of this experiment are shown in the accompanying table.

TABLE V.

Temperature of Experiment -5°C

Date of Experiment 14–II–1934 Air Temperature 18°C

Time of exposure	In lidless dish			In lided dish			Packed with absorbent cotton		
	Total number of tested	Frozen number	% of frozen number to the total number	Total number of tested	Frozen number	% of frozen number to the total number	Total number of tested	Frozen number	% of frozen number to the total number
mins. 40	36	6	16.6	28	3	10.7	26	0	0
1 hr.	35	10	28.5	35	4	11.4	43	0	0
2	41	14	34.1	32	4	12.5	35	0	0
3	51	19	37.2	29	3	10.4	29	0	0
5	33	12	36.3	35	5	14.3	33	1	3.0
8	35	17	48.6	38	10	27.3	27	0	0
14				30	9	30.0	38	2	5.2
24	38	21	55.3	36	14	38.8	51	2	3.9

The table shows clearly, as discussed above, that the lowering of the supercooling point may be obtained by preventing either mechanical shocks from outside, or by slowing the rate of cooling. The result of the experiment shows that about a half of the larvae kept in lidless dish froze after 24 hours, while in the case of the larvae packed with the cotton only 3.9% froze and froze in the case of the dish with a lid 38.8%.

IV. Discussion

It has for long been a known fact that when an organism is exposed to low temperatures to be made frozen, it dies in most cases even if it is later brought back to the ordinary temperature. This is the freezing death of the organism, which is due to the freezing of the protoplasm. As for the phenomenon and mechanism of this freezing death, there have been published a large number of theories especially in botany. For instance an old theory states that the freezing death of the plant is caused by the mechanical destruction of the cell body which is due to the formation of ice-crystals. The modern theory, however, states that the mechanical destruction is not great but the most probable cause is the dehydration of the protoplasm or its coagulation which is brought about from the ice formation in the intercellular space of the plant.

In the animal, on the contrary, the study on the cause of the freezing death has hitherto been so neglected that we can not at present say how the animal dies from freezing, i. e. whether the cause is purely mechanical or physico-chemical. In the case of the freezing death of my insect, *Chaetodacus cucurbitae* COQ., I also could not determine the cause.

As for the general problem of cold-death, on the other hand, it is my great regret that most zoologists are merely of the opinion that the cold-death of the animal is caused only from the freezing, i. e. from the formation of ice crystals in the protoplasm, and have not taken notice of the fact that the death of the animal caused by cold is not only due to the freezing of the body fluid but also to supercooling. It is certain from the result of my experiment that when the supercooled state i. e. the state at which the animal is never brought to be frozen, though it is exposed to lower temperatures below the freezing point of the body fluid, continues for a certain time, the animal never recover its vitality, even if it is again brought back to the ordinary temperature.

To which mechanism is due this supercooling death—I would call this kind of cold death as such—I can say nothing as far as my present experiment is concerned. But it is safe to say that the mechanism of this supercooling death is quite different from freezing death, because in the latter case the formation of the ice-crystals is at least the governing cause, while in the supercooling state no ice is formed.

I believe that this kind of cold-death is very common in nature, for many hibernating animals are frequently brought to the supercooling state in winter, when the out-door temperatures go down very low without giving any mechanical disturbance to the animal body, which comes for instance from wind or from other causes. In fact, when the air-temperature drops, many insects become inactive and enter in the hibernating period hiding themselves under soil, stone or bark. These places are free from the mechanical disturbances which break the supercooling state of the insects, as the present experiment shows, and make them freeze. It is therfore quite evident that in winter the insects are frequently exposed to the supercooling state but not to the freezing state. I think the fact that though protected in such places, the number of insects decreases remarkably after a severe of winter, is due to the fact that they are killed by supercooling.

Thus we clearly divide the cold-death of insects into two groups, i. e. freezing death and supercooling death. GREVELLUS reported that larvae of a moth, *Nygmia phaeorrhoea* DON., which survived at -31°C in their nest, died in a few hours by taking them out of their nest to air-temperature of -14°C; KULAGIN also described that eggs of a moth, *Porthetria dispar*, did not die even at -50°C, but all died at -19°C when the moth was deprived of its hair, which stuck on the surface of eggs. These facts show that the increase of the rate of cooling breaks the supercooling state and kills the insects sooner than in the cooling in the protected condition.

V. Summary

1. When the insects are exposed to low temperatures below the freezing point of their body-fluid, they do not always freeze immediately but remain in a supercooling state, if the conditions of cooling are

such as to keep them at a still state without being given mechanical shocks or such as to keep the rate of cooling slow.

2. When the supercooling state continues for a certain time, the insects eventually die though ice-crystals are never formed in their bodies. This mechanism of cold-death, the supercooling death, has not hitherto been described in insect physiology, in which the freezing death has only been treated.

3. The mechanism of death in the supercooling state is believed to be quite different from that due to freezing, for the time required to kill the insects from supercooling is far longer than that from freezing. All the larvae of a fruit-fly, *Chaetodacus cucurbitae* COQ., are killed in 25 minutes exposure, when they are completely frozen at −3.4°C; in 20 minutes at −5°C; and in only 4 minutes at −12°C. On the contrary as long as 16 hours is necessary to kill them from supercooling at −3.4°C; 8 hours at −5°C; and 2 hours at −12°C.

4. I believe that in nature the phenomenon of supercooling is very common in hibernating cold-blooded animals, for in winter they generally hide themselves in an inactive state in protected places so that they are free from any mechanical disturbances or directly from outdoor temperatures, and it seems to me to be a reasonable conclusion that such conditions of hibernation avoid the freezing death, due to the severe cold of winter.

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Studies on the Death-Temperature of a Fruit-fly, *Chaetodacus cucurbitae* COQUILLETT, at the Frozen State and the Influence of Supercooling upon Its Temperature

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I. Introduction

It has been reported in the previous paper that in the cold-death of insects we should distinguish the unfrozen death which is caused from the supercooling of their bodies from that due to freezing. In this paper we deal with studies on the death-point of the same insect as I employed in the previous experiments in the course of freezing of its body fluid, and the influence of the duration of supercooling on that point.

According to a famous study by BACHMETJEW, in the process of the cooling of insects, the body temperature rebounds rapidly, as soon as the ice crystals are formed in their body. This time of the temperature rebound corresponds, however, not to the time of complete freezing of the insect, namely not to the completion of the freezing of the total body fluid, but to the beginning of the ice formation at the point of attachment of the thermocouple used for measuring temperature. From this time on, the body temperature of the insect again continues to go down. BACHMETJEW declared this temperature falling followed after rebound to be an indication of the " Abkühlung der erstarrenden Säfte ". But I am of the opinion that this refalling of temperature denotes the process of temperature equilibrium between BACHMETJEW's so called " Abkühlung der erstarrenden Säfte " and

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the temperature rising due to the liberation of heat energy caused from the freezing of the remaining part of the body fluid. In fact according to the experiment of SACHAROV, it was proved that in general the body fluid of the insect does not completely freeze at once at low temperatures such as -10° or -15°C and that the point of N in the original temperature curve of BACHMETJEW (see Fig. 9 BACHMETJEW 1907) indicates only the time of beginning of the ice form tion in the insect body.

If this is true, a question will arise when is in the insect killed from freezing, that is, how much ice crystals should be in the insect body in order that the insect may be killed by freezing. In order to determine this problem, I carried out some experiments which I would report this article.

I take this opportunity of thanking Prof. T. SHIRAKI and Prof. K. KOIDSUMI for having suggested the problem.

II. Material and Methods

As was mentioned in the introduction the exact point of freezing death must be solved from the amount of ice crystals formed in the body. The practice is, however, not always easy, so instead of this, I recorded the falling of body temperature, which is followed after the beginning of the freezing from which I could determine the point of death in the course of freezing. The falling of the body temperature was determined with a thermocouple, one end of which is kept at O°C while the other contacts with body surface of the larvae by ROBINSON's method.

The larvae in the 3rd stage were exposed to low temperatures of thermostat, and the falling of the body temperature in the course of cooling was noted. When the body temperature of the material fell to a given degree, it was again brought to a normal temperature and determined whether it was still alive or dead. As the sign of death, I took the activity of the material. The living reserve their special peristaltic movement, but in the dead such a movement can not been seen. Besides these living and non-living materials, an intermediate stage was recognized, in which the larvae could move only their mouth parts. In this stage, the larvae were considered to be on the verge of death.

III. Results of Experiments

A. Determination of Death-Point at Freezing State

The larvae were exposed to temperatures of -5°, -8° and -11°C respectively, and were given mechanical shocks in order to be made frozen by the same method as mentioned in the previous paper, as soon as the body temperature falls below their freezing point. As soon as the formation of ice crystals takes place in the insect body the body temperature rebounds, but then falls again. When it falls to a given degree, the larvae were taken out from the thermostat to the normal room-temperature (15-20°C) and protected by a piece of a cucurbitaceous fruit (*Cucumis sativus*, LINN.). The examination to test whether the larvae survive or not was undertaken after 24 hours. These results are shown in Fig. 1.

From this figure the percentages of the larvae survived, killed, and brought to be on the verge of death were calculated, and are shown in the accompanying table.

No larvae the body temperature of which again fell to -4.0° or -3.6°C after rebound could survive after having been set back to the room temperature. In the case of -3.2°C a greater part of the larvae also died, but a few were on the verge of death. In -2.9° and -2.6°C, on the other hand about 15% of the larvae died, about 50% were on the verge of death, and remaining 35% survived. In the case of -2.2°, -1.9° and -1.5°C no larvae were killed, a few brought to the verge of death, but the greater part remained still alive. Finally in -1.2° and -0.8°C no larvae could be found which were either dead or on the verge of death, all being still alive.

Thus we can see the fact that the deeper the larval temperature falls, the higher becames the percentage of deaths and vice versa. From such a generallization we may conclude the that more ice-

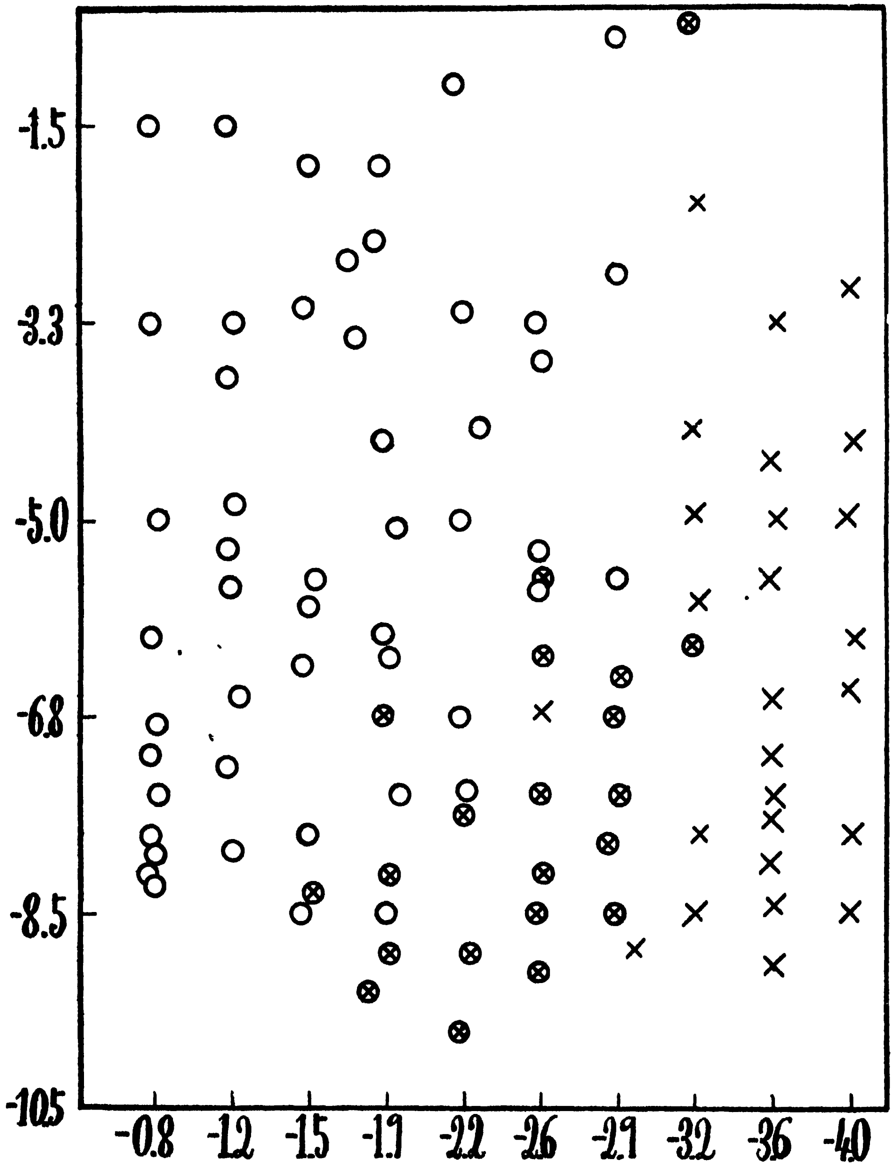

Fig. 1.

Showing the larvae of fruit-fly, survived (○) completely killed (×) and brought to be on the verge of death (⊗), when taken out of thermostat to the normal room-temperature after their body temperatures to the temperatures shown in the abscissas, the ordinates represents the temperature of the larvae to which they were brought to be supercooled.

crystals that are formed in the body, the higher is the mortality of the insect, for it may be assumed that the formation of the ice-crystals

TABLE I.

Body temperature at which larvae were taken out of thermostat	Number of larvae tested	Larvae survived		Larvae on the verge of death		Larvae dead	
		Number	% to the number of tested	Number	% to the number of tested	Number	% to the number of tested
−0.8±0.2°C	11	11	100	0	0	0	0
−1.2±0.2	9	9	100	0	0	0	0
−1.5±0.2	8	7	87	1	13	0	0
−1.9±0.2	14	10	71	4	29	0	0
−2.2±0.2	9	6	67	3	33	0	0
−2.6±0.2	11	4	36	6	55	1	9
−2.9±0.2	9	3	33	5	56	1	11
−3.2±0.2	8	0	0	2	25	6	75
−3.6±0.2	11	0	0	0	0	11	100
−4.0±0.2	7	0	0	0	0	7	100

is proportional to the falling of the temperature of the insect after rebound, as mentioned in the introduction.

B. Influence of the Duration of Supercooling State upon the Freezing Death

In this section are described the results of experiments to determine what influences has the duration of the supercooling upon the percentage of death of the fruit-fly larvae due to freezing.

The larvae were cooled slowly and kept still in the thermostat of −2.9°C to be kept in supercooled state by means of the same method as mentioned in the previous experiment. Then mechanical shocks were given to the larvae after they had been kept in the supercooled state for a given number of hours, in order to make the supercooled state break, and to cause the formation of ice crysatls in the body of the insect. When the body temperature rebounded and fell again to a given temperature the larvae were taken out from the thermostat to the normal room-temperature and reared on the food plant as mentioned previously.

The accompanying figure shows the larvae that survived (O), that were completely dead (×), and those that were brought to the verge of death (●), which had been made frozen after various durations of supercooling.

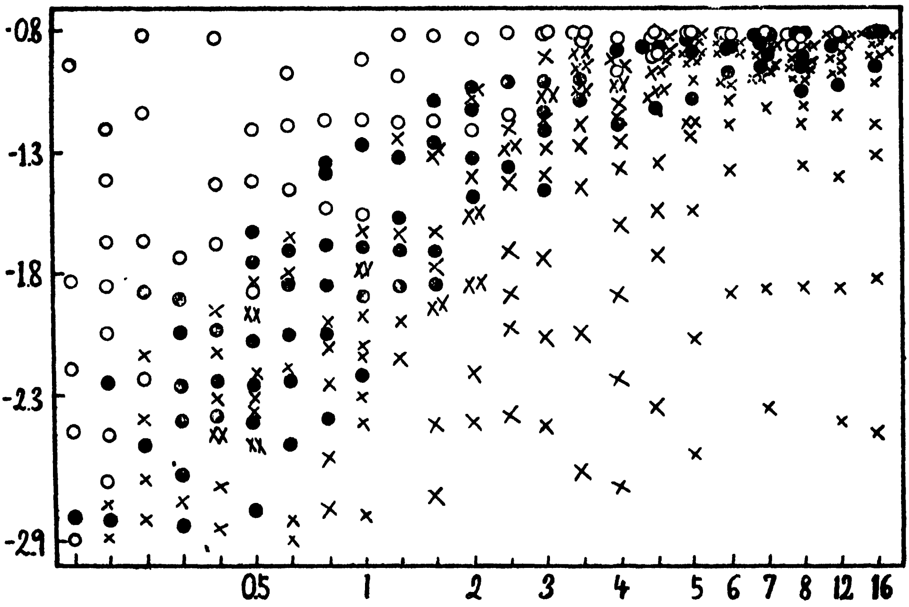

Fig. 2.

Effect of the duration of supercooling on the percentages of fruit-fly, survived (O), dead (×) and brought to be on the verge of death (●). Abscissa denotes the duration of undercooling (-2.9°C) in hours, ordinates the body temperature at which the larvae were put back to the room-temperature from low temperature thermostat. cf. Table IIa-IId.

From Fig. 2 are produced four general tables (Table IIa-IId) in order to make the results more easily understand.

Table IIa-IId. Effect of the duration of supercooling on the larvae of fruit-fly, Table IIa indicates the results when the larvae were taken out of the thermostat, when their body-temperature showed -0.8° to -1.3°C; IIb. -1.3° to -1.8°C; IIc. -1,8° to -2.3°C; IId. -2.3° to -2.9°C. cf. Fig. 2.

From the figure and the tables it may be clearly seen that the percentage of the larvae survived, dead, or brought to the verge of death differs greatly according to the duration of supercooling in all

TABLE IIa.

-0.8—-1.3°C

Duration, during which larvae were kept at supercooling state	Number of larvae tested	Larvae survived		Larvae on the verge of death		Larvae dead	
		Number	% to the number of tested	Number	% to the number of tested	Number	% to the number of tested
5 mins.	1	1	100	0	0	0	0
10	1	1	100	0	0	0	0
15	2	2	100	0	0	0	0
20	0	0	0	0	0	0	0
25	1	1	100	0	0	0	0
30	1	1	100	0	0	0	0
40	2	2	100	0	0	0	0
50	2	1	50	0	0	1	50
60	3	2	67	1	33	0	0
80	4	3	75	0	0	1	25
100	6	2	33	2	33	2	34
2 hrs.	6	2	33	2	33	2	34
2.5	6	2	33	1	17	3	50
3	10	2	20	3	30	5	50
3.5	13	3	23	2	15	8	62
4	12	2	17	2	17	8	66
4.5	17	5	29	3	18	9	53
5	15	2	13	4	26	9	61
6	14	2	14	4	29	8	67
7	16	1	6	5	31	10	63
8	19	3	16	5	26	11	58
12	13	1	8	3	23	9	69
16	15	0	0	4	26	11	74

TABLE IIb

-1.3——-1.8°C

Duration, during which larvae were kept at supercooling state	Number of larvae tested	Larvae survived		Larvae on the verge of death		Larvae dead	
		Number	% to the number of tested	Number	% to the number of tested	Number	% to the number of tested
5 mins.	0	0	0	0	0	0	0
10	2	2	100	0	0	0	0
15	1	1	100	0	0	0	0
20	1	1	100	0	0	0	0
25	2	2	100	0	0	0	0
30	3	1	33	2	67	0	0
40	4	1	25	1	25	2	50
50	6	1	17	2	33	3	50
60	5	1	20	1	20	3	60
80	4	0	0	3	75	1	25
100	3	0	0	1	33	2	67
2 hrs.	5	0	0	2	40	3	60
2.5	3	0	0	1	33	2	67
3	3	0	0	1	33	2	67
3.5	1	0	0	0	0	1	100
4	1	0	0	0	0	1	100
4.5	3	0	0	0	0	3	100
5	1	0	0	0	0	1	100
6	1	0	0	0	0	1	100
7	0	0	0	0	0	0	0
8	1	0	0	0	0	1	100
12	1	0	0	0	0	1	100
16	2	0	0	0	0	2	100

TABLE IIc

-1.8—-2.3°C

Duration, during which larvae were kept at supercooling state	Number of larvae tested	Larvae survived		Larvae on the verge of death		Larvae dead	
		Number	% to the number of tested	Number	% to the number of tested	Number	% to the number of tested
5 mins.	2	2	100	0	0	0	0
10	3	2	67	1	33	0	0
15	3	1	33	1	33	1	34
20	3	0	0	3	100	0	0
25	4	0	0	2	50	2	50
30	7	1	14	2	28	4	58
40	4	0	0	3	75	1	25
50	5	0	0	2	40	3	60
60	5	0	0	2	40	3	60
80	3	0	0	1	33	2	67
100	3	0	0	1	33	2	67
2 hrs.	3	0	0	0	0	3	100
2.5	2	0	0	0	0	2	100
3	1	0	0	0	0	1	100
3.5	1	0	0	0	0	1	100
4	2	0	0	0	0	2	100
4.5	0	0	0	0	0	0	0
5	1	0	0	0	0	1	100
6	1	0	0	0	0	1	100
7	1	0	0	0	0	1	100
8	1	0	0	0	0	1	100
12	1	0	0	0	0	1	100
16	0	0	0	0	0	0	0

TABLE IId

-2.3—— -2.9°C

Duration, during which larvae were kept at supercooling state	Number of larvae tested	Larvae survived		Larvae on the verge of death		Larvae dead	
		Number	% to the number of tested	Number	% to the number of tested	Number	% to the number of tested
5 mins.	3	2	67	1	33		
10	5	2	40	1	20	2	40
15	4	0	0	1	25	3	75
20	4	0	0	3	75	1	25
25	6	0	0	1	16	5	84
30	5	0	0	2	40	3	60
40	3	0	0	1	33	2	67
50	3	0	0	1	33	2	67
60	3	0	0	0	0	3	100
80	0	0	0	0	0	0	0
100	2	0	0	0	0	2	100
2 hrs.	1	0	0	0	0	1	100
2.5	1	0	0	0	0	1	100
3	1	0	0	0	0	1	100
3.5	1	0	0	0	0	1	100
4	1	0	0	0	0	1	100
4.5	1	0	0	0	0	1	100
5	1	0	0	0	0	1	100
6	1	0	0	0	0	1	100
7	0	0	0	0	0	0	0
8	1	0	0	0	0	1	100
12	0	0	0	0	0	0	0
16	1	0	0	0	0	1	100

temperatures at which the materials were brought back to the room-temperature. In every case the percentage of the survivals decreased and that of the deaths increased with the duration of the supercooli

It may consequently be said that the freezing death of the insect is conditioned greatly by the duration of supercooling.

IV. Discussion

It is generally believed that the cause of the cold-death of organisms is due to the formation of ice crystals in their bodies, and a large number of hypothesis have been presented as to the mechanism of such a freezing death, for instance, the protein-coagulation theory by LIDFRÖSS (1907), the theory of the mechanical injuries due to ice formation by MAXIMOV (1914), or the theory on the protoplasmic changes of MOLISCH (1897), STELES (1930). These all are but hypothesis, and any decided explanation has never been published. It is however correct to say that in the freezing death ice crystals are formed either in the cell body or intercellular space. As shown in Fig. 1 and Table 1 all the larvae cooled below -3.6°C died immediately after returning to the room-temperature. Generation of heat in the insect body caused by the formation of ice crystals takes place during the falling of body temperature to -3.6°C or to points lower than this and ice crystals are formed proportionally to the amount of heat evolved. It is consequently obvious that the amount of ice which makes the insect temperature fall to -3.6°C is sufficient to kill completely the larvae. When the body temperature reaches a point not lower than -2.9°, the most of larvae which were only slightly supercooled survived as shown in Fig. 1. From this result I could conclude that the deepness of the supercooling has an effect upon the freezing death of the insect. The results reported in my previous paper in which some of larvae did not die, even though they were frozen, may be due to this effect of supercooling. On the other hand when the larvae were deeply supercooled, lower than about -5°C, almost all of them died, for instance, even in -2.9°C no larvae could survive, or in -2.2°C only two larvae were restored to life. From these results, it is obvious that the duration of supercooling also influences the death point of the larvae. It is for this reason that I carried out the experiment B in this paper. The results were such as to make the assumption true, namely, the longer the time at the supercooled state, the higher was the death point of the larvae. A curve in Fig. 2 shows that within the range of shorter durations of supercooling the critical highest temperature or death point, at which the death of the larvae takes place, becomes higher more rapidly than in the range of longer durations and finally in longer durations than about 6 hours almost all the larvae are killed by such a high temperature as -0.8°C which was proved to be a normal freezing temperature of this larvae. This shows no other than the above-mentioned fact that the supercooling has a marked effect on the freezing death of insect.

V. Summary

1. The body temperature of the fruit-fly, *Chaetodacus cucurbitae* COQ., at which 100% mortality is produced owing to the freezing of the body fluid lies lower than -3.6°C.

2. The depth of the supercooling as well as its duration has a marked effect upon the freezing death of the insect, that is, the deeper or the longer the supercooling, the higher is the death-temperature of the fly.

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STUDIES OF THE SKELETAL STRUCTURE MUSCULATURE AND NERVOUS SYSTEM OF THE ALDER FLY CHAULIODES FORMOSANUS PETERSEN

Takadi MAKI

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I. INTRODUCTION

The order Neuroptera has been considered as the most primitive and morphologically interesting group of Holometabolous insects. The anatomy of the external body parts in the order has been studied by many authors, consequently the knowledge of it has been considerably advanced. On the other hand, although the muscular and nervous systems have received some attention from writers, the knowledge of these systems is very poor. Papers dealing with the external structure of the head and mouth parts of the order have been previously published by MACLENDON (1906), CRAMPTON (1917 a, 1921 d, 1923 b and 1925), ABNEY (1926), MORSE (1931), etc. SNODGRASS (1909), CRAMPTON (1909, 1914 c, 1919, 1920 a, 1926 and 1931) and MORSE (1931) dealt with the external structure of the thorax. The basal segments of the legs have received attention from CRAMPTON and HASEY (1915). There are studies dealing with wing venations by COMSTOCK and NEEDHAM (1898-99), MACLENDON (1906), HANDLIRSCH (1908), TILLYARD (1916-19), COMSTOCK (1918), WITHYCOMBE (1922), CRAMPTON (1922), MORSE (1931), etc. The external genital structure has been the subject of works by STITZ (1909 a), CRAMPTON (1917 d, 1918 a, 1918 b, 1919 a, 1920 a, 1921 c, 1929), NEWELL (1918) and MORSE (1931). The adult nervous system has been dealt with by WITHY-

COMBE (1925), etc., but detailed papers are very few. Only one paper descrived the musculature, i. e. in the study made by MILLER (1931) of *Chrysopa plorabunda.* The present paper deals anatomically with the skeletal structure, the musculature and the nervous system in the adult of *Chauliodes formosanus* PETERSEN belonging to a primitive group of the Neuroptera.

The present work was suggested by and carried out under the direction of Professor T. SIRAKI, to him the writer is much indebted for all the help which has made the present study possible.

II. MATERIAL AND TECHNICAL METHODS

The emergence of *Chauliodes formosanus* PETERSEN occurs in early summer in Formosa, the number of individuals being very rarely abundant. Fortunately the author had opportunities to collect a number of specimens in the neibourhood of Taihoku.

The specimens employed for the study of the skeletal structure were observed in water after soaking in a solution of 5% sodium hydroxide, under a binocular microscope. The material for the observation of the muscular system was preserved by hardening with a solution of 75% alcohol and 2% formaldehyde, and dissected exclusively in water under a binocular microscope. The investigation of the nervous system was carried out with the aid of the microscope as for the preceding observation, from the dissection of the material hardened with the same alcohol formaldehyde solution and the material performed vital staining with a solution of 10% Rongalitweiss and 0.7% sodium chloride and fixed the colour with a solution of 8% ammonium molybdate.

III. SKELETAL STRUCTURE

1. HEAD

The dorso-anterior aspect of the head is eliptical, ovate in form and provided with a broader end on the posterior side at the lateral aspect.

A. Cranium

(Figs. 1, 2, and 3)

The cranium in the present species is not so typically subdivided into three regions, the prostomialreion, the middle region or parietals and the posterior region, as that in generalized insects, because the frontal and the occipital suture are lacking, but it is divisible into four regions, the labrum, the clypeus, the fronto-parieto-occipital region, and the postoccipital region by the clypeo-labral or labral suture, the epistomal suture, and the postoccipital suture.

The anterior surface of the labrum (lr) is distinctly demarcated from the clypeus (cl) by the clypeo-labral or labral suture (ls), and is transverse ellipical in form. The lateral basal portion of the posterior surface in the labrum is thickened to form the so-called torma (to), of which the proximal portion has a small apodeme on which the posterior retractor of the labrum (3) is attached.

The clypeus (cl) is a transverse sclerite distinctly demarcated from the antero-ventral portion of the fronto-parieto-occipital region (fro) by a deep transverse suture or epistomal suture (eps). The distal portion is narrower than the proximal. The latero-proximal corner is considerably thickened to form a round precoila (pcmd) which is articulated with the preartis (prmd) at the anterior base of the mandible.

The fronto-parieto-occipital region includes areas corresponding to the frontalregion, the parietals and the occipital region in generalized insects. The frontal region (fro) in the present species may be vaguely orientated by the situation of ocelli (lo, mo) and anterior tentorial pits, because the frontal suture or boundary between the frontal and the parietal region in generalized insects is usually found between the median ocellus and the lateral ocelli and extends to the anterior tentorial pits. The middle area of the fronto-parieto-occipital region corresponds to the parietals (CRAMPTON, 1921 d) in generalized insects. This area has a faint longitudinal suture or coronal suture (cs) on the median line, a pair of large semispherical compound eyes on the sides, a pair of antennae on the sides of the frontal region, and paired ocelli (lo) on the latero-dorsal sides of the median ocellus (mo) situated on the medio-dorsal portion of the frontal region (fro). The attached portions of muscles on the area are externally elevated. The marginal areas of compound eyes, lateral ocelli, and of antennae, are also elevated, especially on those of the last. The cranical portions surrounding the antennal bases are differentiated in ring-shaped antennal sclerites (asc) (antennale CRAMPTON, 1917 c) by the antennal sutures (asu). The inner margins of lateral portions of the antennal sclerites hinge the lateral bases of antennae, and the inner margins of median portions of the antennal sclerites are provided with median processes (ac) called antacoilae (MACGILLIVRAY, 1923 b) or antennifers (CRAMPTON, 1917 c) and articulated with the median bases of the antennae. The very narrow portions (os) surrounding the compound eyes are also demarcated from the main parietal area by the ocular sutures (osu) of which the internal ridges deeply invaginate and sustain the optic lobes of the brain. These ring-formed sclerites (os) correspond to plates often called the ocular sclerites in other insects.

The postocciput (poc) is narrow, well-thickened, surrounding the dorsal and the lateral side of the occipital foramen. The lateral corner of the posterior margin in the postocciput is prominent and curves forward.

The tentorium (Figs. 1, 2, 3, and 11) consists of anterior, posterior and dorsal arms, and a tentorial body formed by fusion of the internal ends of the anterior and posterior arms, like that in many other insects.

The anterior arm (atn) of the tentorium arises on the lateral end of the epistomal suture (eps) and externally forms a large crescent-shaped pit (atp) which extends from the lateral end of the epistomal suture to the ventral side of the antennal base.

The posterior arm (ptn) of the tentorium which is stouter than the anterior one, but shorter, arises on the area between the gulamental and the postgenal region (gum and pg), and externally forms a large slit-like pit (ptp) of which the ventral end extends to the paracoila (pac) with which the cardo of the maxilla is articulated.

The dorsal arm (dtn) of the tentorium is slender, prolonged from the anterior tentorial arm near the tentorial body, its apex being connected with the cranial wall on the median side of the compound eye by tendinous matter.

B. Antenna

(Figs. 46, 53, 54 and 55)

The antenna consists of a scape (s), a pedicel (pd), and a long flagellum (fl). The scape (s) or first basal segment is stout and cylindrical. The median basal portion of the scape is emaginated and articulated with the antacoila (ac) or median process of the antennal sclerite. The lateral basal portion of the scape is prominent, and hinged on the inner margin of the lateral portion in the antennal sclerite (asc). The median distal portion of the scape is also prominent being hinged to the median basal process of the pedicel, while the lateral distal portion of the same is emarginated and articulated with the lateral basal process of the pedicel (pd).

The pedicel (pd) is the second segment of the antenna, somewhat smaller than the scape, and slightly constricted in the middle portion. The distal portion of the pedicel is cennected with the basal portion of the first segment of the flagellum. The basal portion of the pedicel is provided with a median and a lateral process articulated with the distal portion of the scape as above mentioned.

The flagellum (fl) consists of about sixty segments (very variable) which are equal in length except for several basal shorter segments. The medio-ventral portion of each flagellar segment is prominent, especially in the male.

C. Mandible

(Figs. 1, 2. 3, 9 and 10)

The mandible is a strong thickened hollow appendage, isosceles and hairy at the lateral aspect, horn-like shape curved medially at the antero-dorsal aspect.

The median edge of the mandible is divisible into two regions, the incisor and the molar. The incisor (i) is the apical half of the mandible, one-dentate, pointed and curved medially. The molar (mol) occupying the basal half of the mandible, is broader than the incisor, and bluntly three-dentate.

The latero-anterior basal corner of the mandible is greatly thickened and emarginated to form the so-called preartis (prmd) which is articulated with the precoila (pcmd) projected on the lateral basal corner of the clypeus (cl). The latero-posterior basal corner of the mandible is also well-thickened and forms a semispherical condyle or postartis (mdpr) articulated with a thickened acetabulum or postcoila (mdpc) on the ventral margin of the postgena.

The basal portion of the mandible is provided with two large apodemes, one of which is the adductor apodeme which is an invagination on the membrane of the median basal corner in the mandible, divided into several plate-like branches in the cranial cavity, and the other is the abductor apodeme which is an invagination on the membrane of the lateral base in the mandible near the latero-posterior basal corner of the mandible, smaller than the first and not branched.

D. Maxilla

(Figs. 1, 3, 9 and 47)

The maxilla consists of a cardo, a large stipes, a lacinia, a galea and a five-segmented palpus.

The cardo (ca) is a basal triangular well-thickenek sclerite. The basal corner of the cardo (par) often called the parartis is well-thickened, somewhat emarginated, and articulated with the paracoila (pac) projected on the ventral margin of the postgena (pg) at the antero-ventral end of the pit in the posterior tentorial arm (ptp). On the side of this proximal corner is a long apodeme (ap 12) which is prolonged into the cranial cavity and gives the attaching position to a promotor muscle of the cardo (12). On the internal surface of the cardo is a thickened ridge, which divides the plate into two regions, the median (juxtacardo CRAMPTON, 1916 c) and the lateral (veracardo CRAMPTON), and is attached by adductor muscles of the cardo (13 a, 13 b).

The stipes (st) is a well thickened semicylindrical sclerite clothed with long hairs. It bears the galea (ga) and the maxillary palpus (mxp) on the distal portion, and the lacinia (lc) on the median portion.

The lacinia (lc) is a broad but short lobe on the median side of the stipes. This lobe is less-thickened and hairy, but the basal portion is well-thickened and hairless. The inner base of the lacinia is connected with the membrane occupying the inner side of the stipital plate. The outer base of the lacinia is rigidly attached to the stipes (st).

The galea (ga) is a cylindrical projection provided with a round apex, prolonged from the distal side of the stipes, surrounded by two sclerites, one of which a basal ring-formed well-thickened sclerite, the other a large less-thickened sclerite very thickly covered with fine hairs; both sclerites are separated by a broad membranous area which often deeply invades the lateral and median sides of the second sclerite.

The maxillary palpus (mxp) is a cylindrical and five-segmented appendage projected on the membranous portion of the latero-distal corner in the stipes at the side of the galea. The median portion in the basal segment of the palpus is membranous, consequently the sclerite in this segment does not form a complete cylinder. The second, the third and the fourth segment of the palpus are similar to one another, and form complete cylinders of sclerites, though the median sides of the segments are more or less weakly sclerotized. The apical segment is uniformly thickened, and its terminal portion is somewhat pointed.

E. Labium

(Figs. 2, 12 and 13)

The labium (li) consists of a large gulamentum (gum), a mentum (mn), a prementum (pmn), a pair of ligulae (lg) and a pair of labial palpi (lp).

The gulamentum (gum) is a long large plate, of which the distal margin is roundly emarginated, the lateral margins are fused to the cranium, though the lateral boundaries may be orientated by a slight sinking of the fused portions and by the hairy nature of this plate.

The mentum (mn) is a quadrangular sclerite, of which the distal portion is less-thickened, the proximal margin is provided with two prominences on which the median retractors of the mentum (29) are attached, the lateral portion is curved upward and connected with the hypopharyngeal membranous portion (hp), and the latero-proximal portion is fused to a well-thickened suspensorial rod of the hypopharynx.

The prementum (pmn) is a transverse sclerite, of which the distal and the proximal median margin are emarginated; the lateral portions are curved upward, and the latero-distal portions bear the labial palpi.

The ligula (lg) is a stout but short lobe, which is projected on the distal membranous portion of the labium, weakly sclerotized, and thickly covered with small hairs.

The labial palpus (lp) is projected on the latero-distal corner of the distal sclerite in the prementum (pmn), and three-segmented about equally. The two basal segments resemble each other, the median portions of which are membranous. The terminal segment is entirely thickened and more or less slender than each of the two basal segments.

F. Hypopharynx

(Figs. 11 and 13)

The hypopharynx (hp) is formed by a membranous triangular floor of the mouth cavity, not prominent except for the distal median projection, and provided with a median bar and lateral paired rods on the proximal portion. The median bar (tbh) is a transverse modified spindle-shaped sclerite on which the ventral dilator of the buccal cavity is attached. The lateral rods correspond to the suspensorial rods of the hypopharynx in Orthopteroid insects, prolonged dorsolaterally to the dorso-lateral angles of the mouth to form the oral arms (oa), while the ventral ends are fused to the proximal portion of the mentum (mn).

The salivary common duct (scd) opens between the distal projection of the hypopharynx (hp) and the paired ligulae (lg).

2. THORAX

A. PROTHORAX (1t)

The present paper tentatively treats the neck region as a part of the prothorax.

a. Tergal Region

(Figs. 14, 16, 48 and 49)

The tergal region of the prothorax consists of an anterior membranous portion or dorsal cervical membrane, a main protergal sclerite (pt), a posterior membrane, and a posterior marginal portion of the true protergum (the so-called precosta, acrotergite (SNODGRASS) or notomarginale (CRAMPTON) of mesotergum).

The anterior membranous portion or dorsal cervical membrane is anteriorly connected with the head, and posteriorly with the anterior portion of the protergal plate (pt). On the anterior median portion of the membrane are a pair of small apodemes (ap 53) on which the median dorsal longitudinal muscles (53) are attached near the head.

The main protergal plate (pt) is a large quadrate sclerite of which the lateral and the anterior marginal portion are curved downward. The anterior portion of the plate is less-thickened, and nearly continuous to the dorsal cervical membrane. The posterior portion of the plate is provided with a transverse less-thickened portion.

The so-called precosta (pc) of the mesotergum is very narrow, well-thickened, and posteriorly bordered by the antecostal suture which internally form the first phragma in the thorax.

b. Sternal Region

(Figs. 14, 15, 48 and 49)

The sternal region of the prothorax consists of an anterior ventral flexible portion or ventral cervical region, a large ventral plate, and a posterior membranous area provided with a median apophysis or spina.

On the ventral cervical region are five plates, a median sclerite (amv) and one-paired small sclerites (apv) on the anterior ventral portion, and a pair of large sclerites (vl) on the ventro-lateral portions. The anterior ventral sclerites may correspond to the postgulae or intersternites (CRAMPTON 1917 a, 1921 d). The anterior median ventral or median postgular sclerite (amv) is a less-thickened, semicircular plate situated on the caudal side of the gulamentum (gum), and it gives the attached position to the ventral longitudinal muscles (61). The anterior ventral paired sclerites (apv) are small triangular less-thickened plates situated on the sides of the anterior median ventral sclerite (amv), and give the attached positions to some tergo-sternal muscles (65, 66) of the prothorax.

The ventro-lateral sclerite (vl) is a large elliptical plate situated on the ventro-lateral membranous area of the cervical region, the entire anterior margin is articulated with the head, and the entire posterior margin with the main ventral plate of the prothorax. The sclerite may correspond to a plate called the lateral cervical sclerite or lateral cervicale in other insects. The present paper tentatively treats this plate as an anterior part of the prosternum.

The main ventral plate is subdivided into two regions, the anterior and the posterior. The lateral portion of the anterior region is fused to the pleural region. The posterior region or furcasternum (fus) is a small transverse sclerite situated on the median region between the coxal bases, and provided with a furcal arm on each side.

The spina (si) is small, situated on the median portion of the membrane between the pro- and mesosternum, and projects between the connectives of the ventral nerve cord. The apical portion of the spina attaches the ventral transverse muscles.

The furca (fu) consists of a pair of arms (fua) which are fused to the pleural arms (pam). The furcal pits (fup) formed at the lateral ends of the furcasternum are very large.

c. Pleural Region

(Figs. 11, 42 and 43)

The pleural region is composed of an episternal region fused to the main ventral sclerite, a small and indefinite epimeron (em), and a very small and indefinite trochantin (tn).

d. Fore Leg

(Figs. 31-44)

The coxa (c) is a cylindrical segment, of which the basal portion is stouter than the distal and cut off obliquely; the median and the lateral portion of the distal margin are emarginated, especially so in the latter. The basal marginal portion of the coxa is demarcated from the main coxa by a basicostal suture (bcs) and forms the so-called basicoxite (bc). The basicoxite (bc) is broader at the lateral portion than the median. The middle portion of the lateral of the basicoxite is curved inward, well-thickened, and articulated with the

The proximal portion of the first segment is thickened, somewhat constricted, provided with two processes, the ventral and the longer dorsal, on the margin, but lacks the special articular process. The distal portion of the segment is provided with a slight emargination on the dorsal margin. On the articular membrane attached to the ventral proximal process of the first tarsal segment, there is an apodeme (ap 100) on which the depressor muscles of the tarsus are attached. The tibio-tarsal articulation occurs between the dorsal wall of the constricted basal portion of the first tarsal segment and the dorsal distal emarginated margin of the tibia.

The second segment of the tarsus (ta 2) is shorter than the first and is hairy, especially on the ventral side. The proximal end of the segment is obliquely cut off, and somewhat prominent on the dorsal side which is articulated with the dorsal distal portion of the first tarsal segment.

The third and the fourth tarsal segment (ta 3-ta 4) resemble the second in structure, but the third is shorter and thinner than the second, and the fourth shorter and more or less slender than the third.

The fifth segment of the tarsus (ta 5) is more or less slender and longer than the fourth, but slightly shorter than the first. The proximal portion of the fifth segment resembles that of the fourth. The distal end is provided with three prominences, one (tu) of which is a dorsal broad prolongation known as the Gelenkhöcker (DE MEIJERE, 1901), tubercula (MACGILLIVRAY, 1923) or unguifer (CRAMPTON, 1923 c), of which the distal portion is narrowed and terminates in a hard round process with which the claws articulate, the others are small paired projections on the ventral margin.

The pretarsus (pta) consists of a pair of claws (cw), a calcanea or proximal sclerite of unguitractor plate (ul), a distal sclerite of unguitractor (u 2), and a pair of auxiliae (aux).

The claw (cw) or unguis is horn-like, well sclerotized, curved downward, provided with two longitudinal edges on the ventral side, articulated with the auxilia at the ventral basal corner and with the tubercula at the basal dorsal corner.

The unguitractor plate (ul) or calcanea is a well thickened ventral proximal sclerite which is longitudinally elliptical, concealed under the distal ventral portion of the fifth tarsal segment, and provided with the depressor apodeme extending to the base of the femur.

The second plate of the unguitractor (u 2) (SNODGRASS, 1927) or planta (MACGILLIVRAY, 1923 b; HOLWAY, 1935) is a quadrangular sclerite which is provided with a pair of long hairs (unguitractor setae CRAMPTON, 1923 c) on the distal portion, situated on the distal side of the first plate of the unguitractor, and attached to the auxiliae (aux) at the distal corners.

The auxilia (aux) is a rhombic sclerite which is situated on the distal side of the distal corner in the second plate of the unguitractor (u 2), and attached, proximally, to the latter sclerite and, distally, to the ventral basal corner of the claw. The situation of this sclerite resembles that of the so-called palvillus, but the structure is exceedingly different from that of the palvillus. This sclerite may be probably homologous to the auxilia of MACGILLIVRAY (1923 b) (which is probably homologous to the basipalvillus of CRAMPTON, 1923 c). The term auxilia is here tentatively used of this sclerite.

B. MESOTHORAX (2t)

a. Tergal Region

(Figs. 14, 16, 50-52, 56 and 57)

The mesotergum is divisible into two regions, the large anterior and the posterior as in other winged insects.

The anterior region is a large wing-bearing area called the scutoscutellum (CRAMPTON, 1914), notum or alinotum (SNODGRASS, 1909, 1935). It is subdivided into a large anterior area, a posterior triangular area or scutellum, and two pairs of antero-lateral or prealar sclerites (CRAMPON, 1927).

The first or median prealar sclerite (pram) is a triangular well-thickened plate situated on the membranous area of the latero-anterior portion of the mesotergal region. The dorsal end of a tergo-pleural muscle is attached to the first prealar sclerite.

The second or lateral prealar sclerite (pral) is a very small triangular seclerite which is situated on the side of the first prealar sclerite and provided with an apodeme to which a tergo-pleural muscle is attached.

The anterior area of the alinotum is the largest sclerite of the tergal region. The anterior elevated region in the area may correspond to the so-calledp rescutum, though it is not distinctly divided, and the remainder of the area corresponds to the so-called scutum. The posterior portion of the scutal region (scu) is deeply invaded by the scutellum. The lateral margin of the scutal region is provided with three processes; the first (anw) is an anterior hard projection or so-called anterior notal wing process situated on the latero-anterior corner of the scutal region, and articulated with the anterior process of the first axillary (axl), the second (snw) is a blunt process on the posterior side of the anterior notal wing process (anw), and hinging to the posterior process of the first axillary, and the third (pnw) is a long slender projection called the posterior notal wing process, situated on the latero-posterior corner of the scutal region and articulated with the third axillary (ax 3d). On the lateral marginal area of the scutal region are two pairs of sutures, the first pair extends from the first anterior notal wing processes to the phragmal pits and demarcates the so-called supraalar sclerites (CRAMPTON, 1914 b), while the second pair extends from the apexes of the second anterior notal wing processes (snw) to the anterior bases of the posterior notal wing processes (pnw).

The scutellum (scl) is an elevated triangular sclerite, of which the anterior portion of the latero-posterior corner is laterally prolonged, then curved forward and attached to the base of the posterior notal wing process (pnw), and the posterior portion of the latero-posterior corner is connected with the posterior margin of the wing.

The postscutellum (pc) is a hairless transverse sclerite situated on the posterior side of the scutellum (scl). The median portion of the anterior margin is often notched. The latero-anterior corner extends to the posterior side of the subalare (sa) under the wing base. The lateral portion of the posterior margin is provided with an apodeme to which the intersegmental tergo-furcal muscle is attached.

b. Sternal Region

(Figs. 14, 15, 17, 50–52, 56 and 57)

The mesosternum is divided into three parts, the anterior area, the posterior area (fus) provided with the furca, and the spina (si).

The anterior area is the largest sclerite of the sternal region. It is subdivided into two halves by a median suture. The latero-posterior portion is fused with the episternum.

The posterior area or furcasternum (fus) is a small sclerite situated on the posterior side of the anterior sternal sclerite, and provided with a large median furcal pit. The lateral portion is anteriorly fused with the precoxale and, posteriorly, to the postcoxale. The middle portion of the lateral portion has a sternal coxal process or sternacoila (MACGILLIVRAY, 1923 b).

The spina (si) is a small median apophysis situated on the intersegmental membrane between the meso- and the metasternum, projecting between the connectives of the ventral nerve cord, and giving the median attached position to the net of ventral transverse muscles.

The furca externally forms a large median pit (fup) and, internally, a pair of strong arms, each of which is subdivided into three branches, the first branch (fual) is a broad but short less-thickened lobe on which the dorsal fuca-entopleural muscle (125) is attached, the second (fua 2) is a ventral less-thickened lobe on which the ventral furca-entopleural muscle (126) is attached, and the third (fua 3) is the strongest of the three and fused with the lateral sternal intersegmental apodeme (lsiap) formed on the posterior side of the postero-ventral corner of the epimeron.

c. Pleural Region

(Figs. 14, 50–52, 56 and 57)

The mesothoracic pleuron is divided into two regions, the anterior and the posterior, by a pleural suture. The anterior region includes an episternum, a basalar sclerite, a precoxal bridge, and a trochantin. The posterior region includes an epimeron, a subalare, and a postcoxal bridge.

The pleural suture (psu) is a straight line prolonged from the upper side of the lateral base of the coxa to the under side of the wing base, provided with two slit-like pits (ppa), one (ppal) situated on the middle portion of the suture, and the other (ppa 2) on the pleural coxal process (cc); the suture is internally ridged and having two short apodemes at the internal side of the pits.

The episternum (es) is situated on the anterior side of the pleural suture and divisible into two regions, the dorsal part or anepisternum (aes) and the ventral part or katepisternum (kes), though they are not completely separated. The anepisternum (aes) is larger than the katepisternum, 'convex, provided with a round margin on the anterior side, and with a upward elongation on the dorso-posterior side. The latter elongation ' forms the pleural wing process (SNODGRASS, 1909) or pleuro-alar furcrum (CRAMPTON, 1914) (plw) together with the anterior dorsal prolongation of the epimeron. The katepisternal region (kes) is fused to the latero-posterior corner of the lateral portion of the anterior sternal plate, to the lateral portion of the precoxale (acx), and to the lateral part of the trochantin (tn). The postero-ventral corner of the katepisternal region is prominent, and forming, together with the antero-ventral corner of the epimeron, the pleural coxal process or coxacoila (cc) articulated with the coxartis (cr).

The basalare (b) is a narrow sclerite surrounding the dorso-anterior corner of the anepisternal region (aes), and provided with a plate-like invagination on which strong muscles are attached.

The precoxale (acx) is a narrow sclerite situated on the anterior side of the coxa. The anterior side is attached to the posterior margin of the anterior sternal plate, and the median and lateral sides continuous to the furcasternum and the katepisternum respectively.

The trochantin (tn) is a narrow and semicircularly curved sclerite of which the lateral side is continuous to the katepisternum, and the medio-posterior end is articulated with the anterior basal rim of the coxa. The sclerite is divided into two narrow regions by a suture which is prolonged along the long axis of this sclerite and provided with a small apodeme (ap 128) on which the tergal promotor of the coxa (128) is attached.

The epimeron (em) is a hairy large sclerite which is provided with a deep and wide emergination on the dorsal margin. The anterior dorsal portion is prolonged upward along the posterior margin of the episternum, forming the so-called pleural wing process, together with the episternum, and bearing a wing basal sclerite, the intralar sclerite (CRAMPTON, 1916 a) (is), on the top. The posterior dorsal prolongation of the epimeron is more slender than the anterior dorsal elongation and attached to the lateral margin of the postscutellum (pc). The anterior portion in the ventral margin of the epimeron forms the pleural coxal process or coxacoila (cc) together with the posterior ventral portion of the episternum as already mentioned, and the posterior portion of the same margin is continuous to the lateral portion of the postcoxale.

The subalare (sa) is a small spindle-shaped sclerite which is situated on the large membrane at the posterior side of the pleural wing process (plw) and attached to the posterior portion of the ventral sclerite of the third axillary (ax 3 v). The dorsal marginal portion has a deep invagination on which strong muscles attach. The middle portion of the dorsal margin is connected with the dorsal median plate (mpd) of the wing base by a strong tendon.

The postcoxale (or postcoxal bridge) (pcb) is a narrow sclerite on the posterior side of the coxa, and its median and lateral sides are continuous to the furcasternum and the epimeron respectively.

d. Wing Basal Sclerites

(Figs. 14, 16 and 57)

The mesothoracic wing basal sclerites (alar ossicles by SMITH or pteraliae by CROESCHEL) consist of a tegula, first, second and third axillaries, intralar sclerites, and median plates.

The tegula (tg) is a round hairy flexible sclerite situated on the membranous portion of the anterior wing base at the side of the prealar sclerites (pram, pral).

The first axillary (axl) is a hard dorsal sclerite which has three arms, the anterior, the posterior and the postero-lateral. The anterior arm is a slender hairy and laterally curved elongation, of which the apex is articulated with the anterior basal portion of the second axillary (ax 2d), the median portion is articulated with the concave portion of the first anterior notal wing process (anw), and the median margin is hinged to the apical margin of the first anterior notal wing process. The posterior arm is a basal prolongation which is somewhat stouter than the anterior arm, hairless, and hinged to the second anterior notal wing process (snw). The lateral arm is broad but short and articulated with the basal portion of the second axillary (ax 2d).

The second axillaries consist of two sclerites, the dorsal and the ventral (ax 2d, ax 2v). The dorsal plate (ax 2d) is a very thickened sclerite continuous to the bases of the subcostal and radial veins and provided with two bases, one of which is the anterior basal prolongation articulated with the distal portion of the anterior arm in the first axillary (axl), and the other is longer than the first and articulated with the postero-lateral arm of the first axillary. The ventral plate (ax 2v) is a well-thickened sclerite provided with three processes, the first is basal and articulated with the apex of the episternum, the second is attached to the ventral base of the costal vein, and the third to the ventral base of the subcostal vein.

The third axillaries also consist of two plates, the dorsal and the ventral (ax 3d, ax 3v). The dorsal sclerite (ax 3d) is a well-thickened narrow plate situated on the basal portion of the anal veins, and provided with three median processes, the first is an anterior process articulated with the posterior end of the second median plate (mpd 2), the second is a small process situated on the posterior side of the first process and internally attached to the dorsal end of the strong pleuro-axillary muscle, the third is a posterior process articulated with the apical portion of the posterior notal wing process (pnw). The ventral sclerite (ax 3v) is a narrow plate, of which the proximal portion is articulated with the posterior end of the subalar plate (sa), and the distal or lateral portion terminates in an indistinct margin.

The intralar sclerite (is) is a small hard ventral sclerite of the wing base. The proximal portion is hinged to the apex of the anterior dorsal prolongation of the epimeron, and the distal portion is articulated with the ventral median plate.

In the present species there are three sclerites called the median plates on the wing base, two dorsals and one ventral. The first dorsal median plate (mpdl) is a small narrow well-thickened sclerite situated between the dorsal plates of the second and third axillaries, attached anteriorly to the same second axillary, and articulated posteriorly with the anterior process of the same third axillary. The second dorsal median plate (mpd 2) is larger and thinner than the first, situated on the distal side of the dorsal plate of the second axillary, elliptical and hairy. The ventral median plate (mpv) is a small irregular sclerite articulated proximally with the intralar sclerite (is) and connected internally with the invagination between the first and the second dorsal median plate.

e. Middle Leg

(Figs. 14, 30 and 45)

Like the fore leg, the middle leg consists of a coxa, a trochanter, a femur, a tibia, and a tarsus five-segmented and provided with a pretarsus on the apex, and these structures are similar to those of the fore leg except that the coxa of the middle leg is very different from that of the fore leg, and that the tibia of the same is provided with two spurs on the distal ventral end.

The coxa (c) of the middle leg is hairy, cylindrical, shorter and stouter than the fore coxa. The anterior half of the bacicoxite (bd) is narrow, on the other hand the posterior half of the same is very broad, and forming a large semicircular convex sclerite or meron (m). The basal margin of the coxa is provided with three articular points, the first (cr) is an acetabulum situated on the lateral portion of the basicoxite (bc) and jointing the pleural coxal process or coxacoila (cc), the second is located on the anterior narrow basicoxite (bc) and articulated with the trochantin (tn), and the third (sr) is a thickened acetabulum called the sternartis, located on the median margin of the coxa and articulated with the sternal coxal process or sternacoila (sc). The distal portion of this segment is deeply emarginated at the lateral and the median side, and provided with anterior and posterior trochacoila (trcc) which are articulated with the trochanter as in the case of the fore leg.

C. METATHORAX (3t)

a. Tergal Region

(Figs. 16, 50 and 57)

The metatergum resembles the mesotergum, but the posterior portion of the scutum (scu) is narrower than that of the mesotergum, the portion homologous to the posterior notal wing process of the mesothorax is detached from the main tergum to form the fourth axillary (ax4), and the postscutellum (pc) lacks the antesior notch.

b. Sternal and Pleural Regions

(Figs. 14, 15, 17, 50-52, 56 and 57)

The sternum and the pleuron of the metathorax also resemble those of the mesothorax except that the portion homologous to the postcoxal bridge of the mesothorax is lacking.

c. Wing Basal Sclerites

(Figs 9, 11 and 48)

The wing basal sclerites of the metathorax resemble those of the mesothorax, though in the metathorax the posterior notal wing process is detached from the tergum and added to the wing basal region as fourth axillary (ax4), and the third axillaries (ax3d, ax3v) and the median plates (mpd, mpv) are somewhat different from those of the mesothorax in shape and size.

The dorsal plate (ax 3d) of the third axillaries is larger than that of the mesothorax and divided into two regions, the anterior and the posterior; the first is an anterior large region which is articulated anteriorly with the median plate and connected internally with the strong pleuro-axillary muscle, the second is a posterior hard arm provided with two branches, of which the anterior branch is articulated with the fourth axillary. The ventral, plate (ax 3v) of the third axillaries is smaller and more thickened than that of the fore wing.

The dorsal median plate (mpd) is smaller than that of the mesothorax and undivided.

The fourth axillary (ax4) is a triangular small sclerite, of which the proximal portion is hinged to the latero-posterior margin of the scutum, and the distal end is articulated with the proximal portion of the third dorsal axillary (ax 3d).

d. Hind Leg

(Figs. 14 and 29)

The hind leg is entirely similar to the middle leg except that the former is somewhat longer than the latter.

3. ABDOMEN

The abdomen is long, cylindrical, provided with ten distinct segments, and with a spiracle on each side of the first eight segments. Sexual dimorphism is found on the segments beyond the seventh.

A. FIRST ABDOMINAL SEGMENT

(Figs. 19, 50 and 52)

The first basal segment of the abdomen is cylindrical, somewhat shorter than the other normal abdominal segments, and provided with a large spiracle on the anterior portion of each lateral membranous region.

The tergum is a hairy transverse sclerite which is divided into two regions, the main plate (at) and the posterior plate (or so-called precosta of the following segment) (pc), by a transverse membranous band or so-called intersegmental membrane. The main tergal plate (at) is often provided with a transverse thickened line which expresses the attached portions of anterior ends of external dorsal muscles. The anterior margin of the tergum is thickened, separated from the posterior margin of the postscutellum (pc) in the metathorax by a slender antecostal suture, of which the lateral end is deeply invaginated to form an apodeme (ltiap) on which the intersegmental tergo-furcal muscle is attached. The posterior margin of the tergum is divided from the second abdominal tergum by a broad shallow well-thickened infolding (or so-called antecosta of the segment behind it) (act). The lateral border of the tergum is indistinct.

The sternum is also a transverse sclerite which is divided by the so-called intersegmental membrane into two regions, the anterior main plate (as) and the posterior plate (pcs), the latter is very narrow except for the lateral portion. Each lateral end of the anterior margin in the sternum is provided with an apodeme (lsiap), the apex of which is fused with the posterior or third branch of the furcal arm in the metathorax (fua3). The posterior margin of the sternum is bounded by a shallow well-thickened infolding (acs) from the second abdominal sternum. The lateral margin of the sternum is indistinct as in the case of the tergum.

The first abdominal spiracle (sp) is larger than in the other abdominal segments, while it is similar to the thoracic spiracle in size, but very different from that of the thorax in structure. It is situated on the dorso-anterior portion of the lateral membrane, attached dorsally to the latero-anterior corner of the tergum, and anteriorly to the metathoracic epimeron. The anterior lip or prolabia (prl) is well-thickened, elevated and overhangs the opening of the spiracle. The posterior lip or postlabia (pol) is not so hard as the anterior lip, nor elevated, and is provided with an apodeme or closing rod (cb) on which the occlusor muscle is attached.

The pleural membrane is hairy except for a round elevation situated on the postero-ventral side of the spiracle.

B. TYPICAL ABDOMINAL SEGMENTS (2a-7a)

(Figs. 19, 20 and 58)

The second to the seventh abdominal segments resemble one another. They also resemble the first abdominal segment, but are longer than the latter, lacking apodemes on the antecostae (act, acs), and their spiracles are smaller and more posteriorly situated on the lateral membranes far from the anterior ends of the segments.

C. EIGHTH ABDOMINAL SEGMENT IN THE FEMALE (8a)

(Figs. 20-22)

The tergum of the eighth abdominal segment is shorter than each of the typical abdominal segments, and the posterior tergal division (or socalled precosta of the following segment) is very narrow.

The sternum of the eighth abdominal segment is a well-thickened quadrangular plate of which the posterior margin is slightly produced but provided with a notch on the median portion.

The eighth abdominal spiracle is situated on the posterior portion of the lateral membrane of the eighth abdominal segment.

The female genital aperture (gf) opens on the posterior membrane of the eighth sternal region which is continuous to the ninth sternal membranous portion. The anterior lip of this opening is somewhat prominent having a slight notch on the apex.

D. NINTH ABDOMINAL SEGMENT IN THE FEMALE (9a)

(Figs. 20-22 and 59)

The ninth abdominal tergum (at) is a transverse plate which is divided into two, the anterior a well-thickened and the posterior a less-thickened region, the first surrounds the anterior and the lateral side of the second region, and extends posteriorly to the base of the genital lobe (gl). The intersegmental infolding or antecosta (act) between the ninth and the next tergum is provided with two pairs of small apodemes on which the longitudinal dorsal muscles are attached.

The ventral region of the ninth abdominal segment is occupied by one pair of flattened genital lobes (gl). The genital lobes are less-thickened except for the basal portions, and provided with hairs on the lateral sides. A tube (dsg) called the dorsal sac by HEBERDAY (1931) opens on the median membranous portion between the genital lobes of the ninth abdominal ventral region. The tube is very long (1.5 times as long as the abdomen) and convolved at the dorsal side of the vagina and the spermatheca.

E. TERMINAL ABDOMINAL PORTION IN THE FEMALE (10a-)

(Figs. 20-22 and 59)

The tenth abdominal segment and the segments behind it are reduced and not distinctly divided. The present paper treats these as a terminal portion of the abdomen.

The terminal abdominal portion consists of a median short cylindrical portion and a pair of lateral lobes.

The median short cylindrical portion (prg) is often called the proctiger, almost membranous, though more or less thickened at the anterior portion of the dorsal surface, and provided with anal opening (an) on the posterior end.

The lateral paired lobes are situated on the lateral bases of the proctiger (prg). Each lobe consists of three sclerites, the dorsal plate (at), the ventral plate (pp), and the intercalary round sclerite (cer). The dorsal sclerite (at) is somewhat prominent, the side of which is attached to the intercalary round sclerite (cer). The dorsal sclerites (at) and the dorsal median area between them may probably correspond to the tenth tergal region, since the dorsal longitudinal muscle of the ninth abdominal segment in the male is attached to the anterior end of a plate corresponding to the dorsal plate (at), while the same longitudinal muscle in the female is attached to the anterior end of the dorsal median area which is situated between the dorsal sclerites (at), as shown in the chapter on musculature. The ventral sclerite (pp) is a narrow plate attached to the ventral margin of the intercalary round sclerite (cer). The sclerite (pp) corresponds to a plate called the paraproct and considered as belonging to the ninth abdominal segment by some authors, but this sclerite may be probably considered as a part of the tenth sternal region, since it is situated on the posterior side of the possible intersegmental area, which is continued to the tergal intersegmental border between the ninth and the tenth abdominal segment, and attached to the ventral side of the cercus.

The intercalary sclerite (cer) is round, remarkably convex and clothed with sensory hairs, and it corresponds to the cercus of other insects.

F. EIGHTH ABDOMINAL SEGMENT IN THE MALE (8a)

(Figs. 23-28)

The eighth abdominal tergum (at) resembles that of the seventh, but is slightly shorter, and the posterior marginal portion (or so-called precosta of the ninth tergum) is very narrow.

The eighth abdominal sternal region consists of a sternal plate (as) and a posterior large membranous area. The sternal plate (as) is a U-shaped sclerite occupying the anterior and lateral marginal areas of the sternal region. The posterior end of the sternal region is lined by a membranous infolding on which the sternal longitudinal muscles are attached.

The spiracle (sp) is situated on the posterior portion of the lateral membrane as in the case of the female.

G. NINTH ABDOMINAL SEGMENT IN THE MALE (9a)

(Figs. 23-28)

The ninth abdominal segment consists of a large tergum (at), and a ventral region provided with a genital aperture (gm), a hypandrium, three median lobes, a posterior membranous area and a pair of posterior ventral plates.

The hypandrium (h) is crescent-shaped, and its median portion is feebly sclerotized.

The first genital lobe (mlgl) is a membranous tongue-like projection between the posterior end of the hypandrium (h) and the opening of the ejaculatory duct (ej).

The second genital lobe (mlg 2) is a membranous short tongue-like lobe forming a dorsal lip of the opening of the ejaculatory duct.

The third genital lobe or penis hook (mlg 3) is a large tongue-like and very hard projection situated on the dorsal or posterior side of the second genital lobe. It is provided with a pair of high edges on the ventral side. Its lateral margin is curved upward. The lateral proximal portion is associated with the anterior lateral corner of the ninth tergum, and with the latero-posterior corner of the eighth sternal plate.

The posterior ventral plates (pnas) are one-paired less-thickened quadrangular sclerites which are situated on the sides of the posterior median membranous area in the sternal region of the ninth segment and between the lateral bases of the penis hook (mlg 3) and the paraproct or parapodial plate (pp).

H. TERMINAL ABDOMINAL PORTION IN THE MALE (10a-)

(Figs. 23-28)

The terminal abdominal portion in the male is very similar to that in the female, but the proctiger (prg) is smaller than in the latter case and concealed at the ventral side of the tenth tergal plates or surgonopods (at, 10a-), and the median membranous portions of the tenth tergal plates are clothed with a number of groups of hairs which arise in rows.

IV. MUSCULATURE

1. MUSCLES OF THE HEAD

A. MUSCLES OF THE LABRUM

(Figs. 4 and 11)

1) Compressor of the labrum (1).

The compressor is a very small muscle arising on the mediolateral region in the anterior rabral wall near the clypeolabral or labral ridge (ls) and inserted into the posterior labral wall or epipharynx (epp) just behind the arising position.

2) Anterior retractor of the labrum (2).

The anterior retractor is a median long and thinly layered muscle arising on the median portion of tbe frontal region (fro) just beneath the median ocellus (mo) and inserted into the median basal portion of the labrum (lr).

3) Posterior retractor of the labrum (3).

The posterior retractor is a long flattened muscle arising on the frontal region (fro) at the lateral side of the proximal end of the preceding, and inserted into the apodeme formed on the proximal portion of the torma (to).

B. MUSCLES OF THE ANTENNA

(Figs. 5, 6 and 9)

1) First levator of the antenna (4).

The first levator is a broadly fan-shaped muscle arising on the ventral face of the dorsal tentorial arm (dtn) and inserted into the dorso-median base of the scape (s).

2) Second levator of the antenna (5).

The second levator is a very strong fan-shaped muscle arising on the lateral portion of the anterior arm of the tentorium (atn) and inserted into the dorso-lateral base of the scape (s).

3) Depressor of the antenna (6).

The depressor is a very strong fan-shaped muscle originated on the median portion of the anterior arm of the tentorium (atn) and inserted into the ventral base of the scape (s).

4) Extensor of the flagellum (7).

The extensor is a muscle arising on the lateral basal wall of the scape (s) and inserted into the lateral base of the pedical (pd).

5) Flexor of the flagellum (8).

The flexor is a muscle originated on the median basal wall of the scape (s) and inserted into the menian base of the pedicel (pd).

C. MUSCLES OF THE MANDIBLE

(Figs. 9 and 10)

1) Abductor of the mandible (9).

The abductor is a long muscle arising on the occipital and postgenal regions of the cranium and inserted into the long apodeme formed on the lateral base of the mandible near the posterior articular process or postartis (mdpr) of the mandible.

2) Dorsal or tergal adductor of the mandible (10).

The adductor is a very large muscle occupying almost half the head cavity. It consists of three bundles; the first (10a) is the largest of three and occupies the cephalic dorsal half of the muscle, it arises on the parietal and occipital regions of the head; the second (10 b) is a middle bundle arising on the occipital and postoccipital regions, and the third (10c) is a postero-ventral bundle arising on the postero-lateral portion of the cranium, these bundles being inserted into the large apodeme (ap 10) formed on the basal median angle of the mandible.

3) Ventral or tentorial adductor of the mandible (11).

The adductor is a small muscle arising on the ventral side of the anterior tentorial arm (atn) and inserted into the anterior basal margin of the mandible (md) at the side of the dorsal or tergal adductor apodéme (ap 10).

D. MUSCLES OF THE MAXILLA

(Figs. 9, 10 and 47)

1) Promotor of the cardo (12).

The promotor is long, somewhat fan-shaped, arising on the postgenal region of the head at the posterior side of the abductor of the mandible, and inserted into the long apodeme (ap 12) formed on the proximal lateral corner of the cardo.

2) Adductor of the cardo (13).

This adductor consists of two thick bundles (13a, 13b) arising on the tentorial body (tnb) and prolonged latero-ventrally; one (13a) of these is inserted into the latero-distal portion of the cardo (ca) at the side of the middle ridge in the cardo, the other (13b) which is shorter than the former, is inserted into the median half of the cardo at the median side of the middle ridge in the cardo.

3) Adductor of the stipes (14).

The adductor is strong, arising on the tentorial body (tnb) at the median side of the proximal attachment of the preceding, and inserted into the posterior corner of the proximal median portion of the stipes (st).

4) Cranial flexor of the stipes (15).

The flexor is a very long muscle arising on the postgenal region of the cranium at the posterior side of the promotor of the cardo (12), and inserted into the small apodeme formed on the anterior corner of the proximal median portion of the stipes (st) at the anterior side of the distal attachment of the preceding muscle.

5) Stipital flexor of the lacinia (16).

This is a strong muscle arising on the latero-proximal portion of the stipes (st) and inserted into the median proximal corner of the lacinia (lc) at the distal side of the distal attachment of the preceding muscle.

6) Flexor of the galea (17).

The flexor is a strong and flattened muscle which arises on the proximal portion of the stipes near the proximal corner of the lacinia (lc) and is inserted into the median corner of the posterior base of the galea (ga).

7) Levator of the maxillary palpus (18).

The levator is a slender and long muscle arising on the proximal median portion of the posterior wall of the stipes (st) at the median side of the proximal attachment in the preceding muscle, and attached on the small apodeme formed on the anterior base of the first segment of the maxillary palpus (mxp).

8) Depressor of the maxillary palpus (19).

The depressor is resemblant to the preceding, arising on the proximal median portion in the posterior wall of the stipes (st) at the median side of the proximal attachment of the levator muscle, and inserted into the posterior base in the first segment of the palpus (mxp).

9) Flexor of the second segment of the maxillary palpus (20).

The flexor is slender, arising on the medio-proximal wall in the first segment of the palpus (mxp), and inserted into the median base in the second segment of the palpus (mxp).

10) Extensor of the second segment of the maxillary palpus (21).

The extensor resembles the preceding muscle, and it arises on the lateral basal wall in the first segment of the palpus (mxp), is inserted into the lateral base in the second segment of the palpus.

11) Levator of the third segment of the maxillary palpus (22).

The levator is a slender muscle arising on the dorsal proximal wall in the second segment of the palpus (mxp), and inserted into the the dorsal base of the third segment of the palpus.

12) Depressor of the third segment of the maxillary palpus (23).

The depressor resembles the preceding muscle, arises on the ventral proximal wall of the second segment of the palpus (mxp), and attaches on the ventral base of the third segment of the palpus.

13) Levator of the fourth segment of the maxillary palpus (24).

The levator resembling the preceding muscle arises on the dorsal proximal wall of the third segment of the palpus (mxp), and is attached on the dorsal base of the fourth segment of the palpus.

14) Depressor of the fourth segment of the maxillary palpus (25).

This muscle is a slender bundle of fibers originated on the ventral wall in the third segment of the palpus (mxp), and attached on the ventral base in the fourth segment of the palpus.

15) Levator of the terminal segment of the maxillary palpus (26).

The levator is small, attached on the fourth and terminal segments of the palpus in a similar manner to that of the levators in the other segments.

16) Depressor of the terminal segment of the maxillary palpus (27).

The depressor is resemblant to the preceding, and is attached on the fourth and terminal segments of the palpus in the same manner as the depressors of the other segments.

E. MUSCLES OF THE HYPOPHARYNX AND LABIUM

(Figs. 11 and 12)

1) Retractor of the hypopharynx (28).

The retractor is a very long muscle arising on the latero-proximal portion of the gular region, and attached on the distal portion of the hypopharynx near the salivary orifice.

2) Median retractor of the mentum (29).

The retractor is a median muscle extremely flattened, arising on the wall of the gulamentum (gum) between the posterior tentorial arms (ptn), and inserted into the proximal median portion of the mentum (mn).

3) Median retractor of the prementum (30).

The retractor is a strong and flattened muscle arising on the ventral portion of the posterior tentorial arm (ptn) and inserted into the posterior base of the prementum (pmn) near the median line.

4) Lateral retractor of the prementum (31).

The retractor is resemblant to the preceding muscle, and arises on the posterior tentorial arm (ptn) at the side of the proximal end of the median retractor, and is inserted into the lateral base of the prementum (pmn).

5) Extensor of the labial palpus (32).

The extensor is a stout muscle originated on the lateral basal portion of the prementum (pmn) at the distal side of the distal end in the lateral retractor of the prementum (pmn), and is inserted into the latero-proximal margin of the first segment in the labial palpus (lp).

6) Levator of the second segment of the labial palpus (33).

The levator is a muscle arising on the dorsal basal wall of the first segment of the palpus (lp), inserted into the dorsal basal margin of the second segment of the palpus.

7) Flexor of the third segment of the labial palpus (34).

The flexor is a muscle arising on the median basal wall of the second segment of the palpus (lp), and inserted into the median basal margin of the third segment of the palpus.

8) Dorsal dilator of the common salivary duct (35).

The dorsal dilator is a very stout muscle arising on the latero-proximal portion of the mentum (mn) and inserted into the proximal dorsal portion of the common salivary duct (csd) at the median line. The muscle probably corresponds to the dorsal dilator of the salivary orifice in Orthopteroid insects by WALKER (1931) and MAKI (1935).

9) Ventral proximal dilator of the common salivary duct (36).

The dilator is very strong, fan-shaped, and arises on the proximal lateral corner of the prementum (pmn) at the distal side of the distal end in the lateral retractor of the prementum, and is inserted into the latero-ventral portion of the common salivary duct (scd) at the ventral side of the preceding muscle. The muscle probably corresponds to the proximal muscle of the salivary cup (SNODGRASS, 1928) or the ventral dilator of the salivary orifice (WALKER, 1931; MAKI, 1935) in Orthopteroid insects.

10) Ventral distal dilator of the common salivary duct (37).

This is a slender muscle arising on the distal portion of the prementum (pmn) at the side of the common salivary duct (csd), and inserted into the latero-ventral portion of the common salivary duct (csd) near the salivary orifice. It probably corresponds to the muscle of the salivary cup (SNODGRASS, 1928), the protractor of the hypopharynx (WALKER, 1931) or the ventral distal dilator of the salivary orifice (MAKI, 1935), in Orthopteroid insects.

2. MUSCLES OF THE STOMODAEUM

(Figs. 11)

1) First dorsal or anterior dilator of the buccal cavity (38).

The dilator is a slender muscle arising on the distal portion of the clypeus (cl) at the side of the anterior retractor of the labrum (2), and inserted into the upper side of the buccal cavity.

2) Second dorsal or anterior dilator of the buccal cavity (39).

This muscle consists of two slender bundles arising on the proximal portion of the clypeus (cl) at the side of the anterior retractor of the labrum (2), and inserted into the upper side of the buccal cavity at the posterior side of the preceding.

3) First dorsal dilator of the pharynx (40).

The dorsal dilator also consists of two bundles of fibers arising on the frontal area (fro) near the dorsal side of the epistomal ridge (eps) on the side of the anterior retractor of the labrum (2), and inserted into the upper portion of the pharynx at the dorso-posterior side of the preceding.

4) Second dorsal dilator of the pharynx (41).

The second dorsal dilator is a muscle originated on the frontal area (fro) at the caudal side of the dorsal end in the posterior retractor of the labrum, and inserted into the dorsal wall of the pharynx at the anterior side of the cerebral ganglion (B).

5) Third dorsal dilator of the pharynx (42).

This is a long muscle which arises on the median portion of the parietal region at the postero-dorsal side of the lateral ocelli (10), and is inserted by a spreading base into the dorsal wall of the posterior pharynx.

6) Fourth dorsal dilator of the pharynx (43).

The dilator is a long muscle arising on the median portion of the posterior of the parietal region, and inserted by a stout base into the dorsal wall of the posterior pharynx at the posterior side of the preceding.

7) Retractor of the mouth angle (44).

The retractor is a stout and long muscle arising on the frontal area (fro) at the median side of the second dorsal dilator of the pharynx (41), and inserted into the oral arm of the suspensorial rod of the hypopharynx (oa) at the lateral angle of the mouth.

8) First lateral dilator of the pharynx (45).

The lateral dilator is a muscle originated on the anterior wall of the cranium at the antero-ventral side of the antennal base, and inserted into the lateral portion of the pharynx at the postero-dorsal side of the lower end of the retractor of the mouth angle (44).

9) Second lateral dilator of the pharynx (46).

This is a loose bundle of fibers arising on the inner edge of the dorsal tentorial arm (dtn), and inserted into the lateral wall of the middle portion of the pharynx at the caudal side of the para-oesophageal connectives (Pc).

10) Third lateral dilator of the pharynx (47).

The dilator is a muscle originated on the parietal region at the latero-posterior side of the lateral ocelli (10), and inserted by a spreading base into the lateral wall of the posterior pharynx.

11) Ventral dilator of the buccal cavity (48).

The ventral dilator is an unpaired median muscle arising on the ventral portion of the tentorial body (tnb), passing between the para-oesophageal connectives (Pc), and inserted into the lower side of the mouth.

12) First ventral dilator of the pharynx (49).

The dilator is an unpaired median muscle originated on the anterior surface of the tentorial body (tnb), and inserted into the lower side of the pharynx.

13) Second ventral dilator of the pharynx (50).

This is a muscle arising on the posterior tentorial arm (ptm), diverging and inserted into the ventral wall of the pharynx at the posterior side of tentorial body (tnb).

14) Third ventral dilator of the pharynx (51).

The dilatar is long, it arises on the lower portion of the post-occiput (poc), and is attached to the ventral wall of the pharynx at the posterior side of the preceding.

3. MUSCLES OF THE THORAX

A. MUSCLES OF THE PROTHORAX

(Figs. 48 and 49)

a. Protractor of the Crop and Gastric Caecum (52)

The protractor is a long and very slender muscle arising on the middle portion of the lateral of the protergum (pt), and extending to the third or fourth abdominal segment; its posterior portion is divided into fine branches, some of which are inserted into the posterior wall of the crop, and the others into the gastric caecum.

b. Dorsal Muscles

1) First internal dorsal muscle (53).

The internal dorsal muscle is a very slender bundle of fibers arising on the small apodeme formed on the anterior portion of the cervical dorsal membrane near the median line, and attached on the first phragma or intersegmental infolding between the pro- and meso-terga.

2) Second internal dorsal muscle (54).

The muscle is a bundle of fibers arising on the anterior portion of the medio-lateral region of the protergal plate (pt), and inserted into the first phragma of the thorax (ph) at the side of the preceding muscle.

3) Third internal dorsal muscle (55).

This is somewhat oblique, and shorter than the second internal dorsal muscle, originating on about the middle portion of the medio-lateral region of the protergal plate (pt), and inserted into tbe side of the posterior end of the second internal dorsal muscle.

4) First external dorsal muscle (56).

The external dorsal muscle is somewhat shorter than the second internal dorsal muscle (54), and is originated on the posterior side of the latter and inserted into the anterior side of the posterior end of the second internal dorsal muscle.

5) Second external dorsal muscle (57).

The muscle is shorter than the third internal dorsal muscle (55), arising on the posterior side of the anterior end of the latter muscle, and inserted into the anterior side of the posterior end of the third internal dorsal muscle.

6) Paratergal muscle (58).

The paratergal muscle is a short bundle of fibers arising on the latero-posterior corner of the protergal plate (pt), and inserted into the lateral portion of the first phragma of the thorax (ph) at the side of the dorsal end of the intersegmental tergo-furcal muscle (68).

7) First protergal muscle of the head (59).

This muscle is a loose bundle of fibers arising on the anterior portion of the dorso-lateral region in the cervix, and inserted into the anterior portion of the median in the protergal plate (pt).

8) Second protergal muscle of the head (60).

The protergal muscle is very stout, originating on the anterior portion of the dorso-lateral region in the cervix, and inserted by a spreading base into the middle portion of the median region of the protergal plate (pt).

c. Ventral Muscles

1) First ventral muscle (61).

The ventral muscle is stout, arising on the cervical anterior median ventral plate (amv) situated on the posterior side of the gulamentum (gum), and inserted into the base of the profurcal arm (fua).

2) Second ventral muscle (62).

The second muscle is a very slender oblique bundle of fibers arising on the posterior side of the cervical ventro-lateral sclerite (vl), and inserted into the anterior side of the base of the profurcal arm (fua).

d. Ventral Transverse Muscle (63)

This is a muscle arising on the postero-lateral side of the basal portion of the furcal arm (fua), divergent, and joined to the formation of a common muscular net of ventral transverse muscles.

e. Tergo-Sternal Muscles

1) First internal tergo-sternal muscle (64).

This is a slender muscle, arising on the lateral portion of the protergal plate (pt) near the anterior corner of the plate, and inserted into the anterior cervical vental sclerite (apv) situated on the side of the anterior median ventral sclerite in the cervix (amv).

2) Second internal tergo-sternal muscle (65).

The tergo-sternal muscle is somewhat strong, arising on the lateral portion of the protergal plate at the posterior side of the preceding muscle, and inserted into the anterior cervical ventral sclerite to which the preceding muscle is attached.

3) Third internal tergo-sternal muscle (66).

The third muscle is very slender, arising on the lateral portion of the protergal plate (pt) on the inner side of the preceding muscle, and inserted into the anterior end of the prothoracic main ventral plate at the side of the ventral longitudinal muscle (61).

4) Anterior intersegmental tergo-furcal muscle (67).

The muscle is very long, oblique, arising on the dorso-lateral portion of the postocciput, and inserted into the profurcal arm at the side of the posterior end of the first ventral muscle (61).

5) Posterior intersegmental tergo-furcal muscle (68).

The intersegmental tergo-furcal muscle is a strong bundle of fibers arising on the lateral portion of the first phragma (ph) between the third internal dorsal muscle and the paratergal muscle (55 and 58), and inserted into the profurcal arm (fua).

6) First external intersegmental tergo-sternal muscle (69).

The muscle is a strong bundle of fibers arising on the dorso-lateral portion of the postocciput (poc) and inserted into the middle portion of the cervical ventro-lateral sclerite (vl).

7) Second external internal intersegmental tergo-sternal muscle (70).

The muscle is strong, originating on the dorso-lateral portion of the postocciput (poc) at the upper side of the dorsal end of the first external intersegmental tergo-sternal muscle (69), and inserted into the cervical ventro-lateral sclerite (vl) at the side of the ventral end of the first external intersegmental tergo-sternal muscle (69).

8) Third external intersegmental tergo-sternal muscle (71).

A short muscle, arising on the dorso-lateral portion of thc post-occiput at the anterior end of the preceding muscle, and inserted into the lateral portion of the cervical ventro-lateral sclerite (vl).

9) First external tergo-sternal muscle (72).

The muscle is very slender, arising on the lateral portion of the protergal plate (pt) on the outer side of the dorsal ends of the internal tergo-sternal muscles, and inserted into the anterior lateral portion of the cervical ventro-lateral sclerite (vl).

10) Second external tergo-sternal muscle (73).

The muscle is originated on the posterior side of the preceding muscle and inserted into the latero-posterior corner of the cervical ventro-lateral sclerite (vl).

f. Tergo-Pleural Muscles

1) First tergo-pleural muscle (74).

The muscle is a bundle of fibers connecting the anterior lateral corner of the tergal plate with the anterior lateral corner of the prothoracic main ventral plate.

2) Second external tergo-pleural muscle (75).

This is short, resembling the preceding muscle, and connected with the tergal plate and the prothoracic ventral plate at the posterior side of the latter muscle.

3) Third tergo-pleural muscle (76).

The muscle is an oblique bundle of fibers originating on the lateral margin of the protergal plate (pt) on the posterior side of the fourth external tergo-sternal muscle (75), and inserted into the dorsal margin of the episternum (es).

4) Fourth tergo-pleural muscle (77).

The muscle is short, arising on the latero-posterior marginal portion of the protergal plate (pt), and inserted into the dorsal portion of the episternum (es) on the posterior side of the posterior end of the preceding muscle.

5) First intersegmental tergo-pleural muscle (78).

This is a very small bundle of fibers arising on the latero-posterior corner of the protergal plate (pt), and inserted into the membranous portion on the anterior side of the first thoracic spiracle.

6) Second intersegmental tergo-pleural muscle (79).

The second muscle, resemblant to the preceding, is attached dorsally to the latero-posterior corner of the protergal plate and ventrally to the intersegmental lateral membrane, at the posterior side of the first intersegmental tergo-pleural muscle.

g. Leg Muscles Arising on the Thorax

(Figs. 7, 31, 44, 48 and 49)

1) First tergal promotor of the coxa (80).

The promotor is a slender muscle arising on the middle portion of the latero-dorsal region in the protergal plate (pt), and inserted into the anterior proximal margin of the coxa.

2) Second tergal promotor of the coxa (81).

The second muscle is very slender, arising on the lateral portion of the protergal plate (pt) near the latero-posterior corner of the plate, and inserted into the anterior proximal margin of the coxa like the preceding muscle.

3) Tergal remotor of the coxa (82).

The tergal remotor is strong, flattened laterally, arising on the latero-posterior portion of the protergal plate (pt) at the anterior side of the dorsal attached portion of the preceding muscle, and inserted into the posterior proximal margin of the coxa.

4) Pleural remotor of the coxa (83).

The pleural remotor is a short but stout muscle arising on the pleural arm, and inserted into the latero-posterior basal rim of the coxa.

5) First sternal promotor of the coxa (84).

This muscle is a long and slender bundle of fibers arising on the posterior lateral corner of the cervical ventro-lateral sclerite (vl), and inserted into the anterior basal rim of the coxa. The muscle may correspond to the musculus microsterni secundus (VOSS, 1905) or the cruciate rotator of the head (DU PORTE, 1920) in *Gryllus*, though the muscles of both sides in the present species are rather parallel to each other than cruciate. The present author considers that this bundle should be included in the coxal muscles, since the posterior end of the muscle is usually attached to the coxa which is actively movable, while the anterior end of the same is attached to the less movable ventral plate.

6) Second sternal promotor of the coxa (85).

The sternal promotor is short, flattened, somewhat fan-shaped, arising on the basisternal region at the anterior side of the furca (fu) near the median line, and inserted into the anterior basal rim of the coxa at the median side of the posterior end of the first sternal promotor (84).

7) Posterior sternal remotor of the coxa (86).

The sternal remotor is a short muscle arising on the furcal arm (fua), inserted into the postero-median basal rim of the coxa.

8) Pleural abductor of the coxa (87).

The abductor is a very stout muscle arising by a widely spreading base on the dorsal margin of the episternum (es), and inserted into the antero-lateral basal rim of the coxa.

9) Depressor of the trochanter (88).

The depressor is a very stout bundle of fibers arising on the ventral surface of the furcal arm (fua), inserted into the apodeme on the ventral base of the trochanter (trc).

h. Leg Muscles Arising on the Leg Segments

(Fig. 31)

1) First levator of the trochanter (89).

The levator is a strong muscle arising by a spreading base on the middle portion of the anterior coxal wall, and inserted into a common levator apodeme on the dorsal base of the trochanter (trc).

2) Second levator of the trochanter (90).

The second levator is long, arising on the lateral basal coxal wall, and inserted into the common levator apodeme on the dorsal base of the trochanter (trc).

3) Third levator of the trochanter (91).

The third levator is a short muscle arising on the middle portion of the posterior coxal wall, and inserted into the common levator apodeme like the preceding muscle.

4) Fourth levator of the trochanter (92).

The fourth levator is a short and slender muscle originated on the posterior coxal wall at the median side of the preceding, and inserted into the common levator apodeme.

5) First coxal depressor of the trochanter (93).

The first depressor is a large muscle arising by a spreading base on the anterior basal coxal wall at the median side of the second levator of the trochanter (90), and inserted into the apodeme on which the furcal depressor of the trochanter (88) is attached. It is very often divided into two bundles.

6) Second coxal depressor of the trochanter (94).

The second muscle is shorter than the first coxal depressor, arising on the anterior coxal wall at the outer side of the latter muscle, and inserted into the common depressor apodeme of the trochanter.

7) Third coxal depressor of the trochanter (95).

The third muscle is a short bundle of fibers arising on the middle portion of the postero-median coxal wall at the proximal side of the basal end of the fourth levator (92), and inserted into the common depressor apodeme.

8) Reductor of the femur (96).

The reductor is a short muscle arising by a widely spreading base on the posterior wall of the trochanter (trc), and inserted into the middle portion of the posterior base of the femur (f).

9) Levator of the tibia (97).

The levator is a strong muscle arising on the dorsal wall of the femur (f) by a very widely spreading base extending from the basal portion of the segment to the distal portion of the same, and attached to a long apodeme (ap 97) formed on the dorsal base of the tibia (ti).

10) Depressor of the tibia (98).

The depressor is a very long muscle divided into four bundles of fibers. The first bundle (98 a) arises on the anterior basal wall of the trochanter (trc), the second bundle (96 b) is the largest of the four and originated on the proximal half of the ventral femoral wall, the third bundle (98 c) on the distal half of the anterior femoral wall, and the fourth bundle (98 d) on the distal half of the posterior femoral wall, and all these are insertedi nto a long slender apodeme (ap 98) formed on the ventral basal portion of the tibia (ti).

11) Depressor of the tarsus (99).

The depressor is a small two-bundled muscle arising on the ventral wall of the tibia (ti), and inserted into the ventral base of the tarsus (ta).

12) Depressor of the pretarsus (100).

The depressor is a long muscle extending from the femoral segment to the terminal segment of the tarsus, arising on the posterior basal portion of the femur (f), and inserted into a long apodeme formed on the proximal portion of the unguitractor plate (u) of the pretarsus (pta).

13) Ventral transverse muscles of the tarsus (101).

The muscles are present on each distal ventral portion of the first four tarsal segments and on the proximal ventral portion of the first tarsal segment. They are very small transverse muscles attached to the ventral walls of tarsal segments (ta) across the dorsal side of the depressor apodeme of the pretarsus (ap 100).

B. MUSCLES OF THE MESOTHORAX

(Figs. 50-52, 56 and 57)

a. Dorsal Muscles

1) First internal dorsal muscle (102).

The internal dorsal muscle is a very stout bundle of fibers arising on the first phragma (ph1) near the median line, and inserted into the second phragma (ph2) near the median line.

2) Second internal dorsal muscle (103).

The second muscle very stout and resembling the preceding muscle is attached anteriorly to the first phragma (ph1) and posteriorly to the second phragma (ph2) at the side of the first internal dorsal muscle.

3) Third internal dorsal muscle (104).

The third muscle is very slender, oblique, arising on the first phragma (ph1) at the side of the anterior end of the preceding muscle, and inserted into the lateral portion of the second phragma (ph2).

4) First external dorsal muscle (105).

This is a bundle of fibers arising by a spreading oblique base on the anterior portion of the scutellum (scl), and inserted into the anterior end of the postscutellum (pc) near the median line.

5) Second external dorsal muscle (106).

The second muscle is a strong oblique bundle of fibers arising on the latero-median portion of the middle of the scutum (scu), and inserted into the lateral portion of the second phragma (ph2) at the outer side of the posterior end of the third internal dorsal muscle (104).

b. Ventral Muscles

1) First ventral muscle (107).

This is a longitudinal very stout bundle of fibers connecting anteriorly with the posterior face of the profurcal arm (fua), and posteriorly with the anterior face of the mesofurcal arm (fua).

2) Second ventral muscle (108).

The second muscle is very slender, originating on the ventrolateral portion of the intersegmental membrane between the pro- and mesothorax, and inserted into the anterior face of the mesofurcal arm (fua) at the side of the posterior end of the first ventral muscle.

c. Ventral Transverse Muscles

1) Anterior ventral transverse muscle (109).

The transverse muscle arises on a small apodeme (ap 109) at the ventro-lateral portion of the intersegmental membrane between the pro- and mesothorax, and joins the formation of a common net of ventral transverse muscles. The latter net attaches to the prothoracic and mesothoracic spinae projecting between the connectives of the ventral nerve cord.

2) Posterior ventral transverse muscle (110).

The muscle arises on the median base of the furcal arm (fua), divides into two branches, one prolonged forward, and the other backward, and joins the formation of the common ventral muscular net.

d. Tergo-Sternal Muscles

1) Intersegmental tergo-furcal muscle (111).

The muscle connects dorsally with the lateral portion of the second phragma (ph2), and ventrally with the mesofurcal arm (fua).

2) First tergo-sternal muscle (112).

The tergo-sternal muscle is a thick bundle of fibers arising on the medio-lateral portion of the scutum (scu) at the antero-lateral side of the anterior end of the second external dorsal muscle (106), and inserted into the median portion of the basisternal region (bs).

3) Second tergo-sternal muscle (113).

The second muscle is very thick, arising on the scutum (scu) at the latero-anterior side of the dorsal end of the first tergo-sternal muscle (112), and inserted into the basisternal region (bs) at the side of the ventral end of the latter muscle.

e. Tergo-Pleural Muscles

1) First tergo-pleural muscle (114).

The tergo-pleural is a small muscle originating on the first or median prealar sclerite (pram), and inserted into the anterior corner of the basalare (b).

2) Second tergo-pleural muscle (115).

The tergo-pleural muscle is a small fan-shaped bundle of fibers arising on the apodeme of the second or lateral prealar sclerite (pral), and inserted into the dorsal portion of the episternum (es) on the anterior side of the pleural wing process (plw).

3) Third tergo-pleural muscle (116).

This is longer than the preceding muscle and arises by a spreading base on the ridge of the suralar sclerite (su) at the anterior side of the anterior notal wing process (anw), and is inserted into the anterior end of the basalar invagination.

4) Fourtn tergo-pleural muscle (117).

The fourth is a muscle arising on the second anterior notal wing process (anw) at the lateral portion of the scutum (scu), and inserted into the first or dorsal pleural arm (pami).

5) Fifth tergo-pleural muscle (118).

The fifth muscle is slender, arising on the lateral margin of the scutum (scu) at the median side of the posterior notal wing process (pnw), and is inserted into the pleural ridge at the upper side of the dorsal pleural arm (pami). It may correspond to the ninth lateral muscle in *Gryllus* by DU PORTE (1920) and to the second alar muscle in *Megacrania* by MAKI (1935).

f. Special Wing Muscle

Pleuro-axillary or pleuro-alar muscle (119).

The muscle is short, strong and divided into two bundles, one (119 a) arising on the dorsal portion of the pleural ridge, and the other (119 b) on the episternum (es) at the anterior side of the fifth tergo-pleural muscle (118), and both are inserted into the dorsal plate of the third axillary (ax 3d).

g. Pleural Muscle

Epimero-subalar muscle or pleural depressor-extensor of the wing (120).

This muscle is a thinly layered bundle of fibers arising by a very widely spreading base on the posterior region of the epimeron (em), inserted into the posterior portion of the subalare (sa).

h. Muscle of the Spiracle

Occlusor of the first thoracic spiracle (121).

The occlusor of the first thoracic spiracle is a very small muscle arising on a very small indefinite sclerite or subspiraculare (CRAMPTON, 1927) at the ventral side of the spiracle, and is inserted into the ventral portion of the spiracle.

i. Sterno-Pleural Muscles

1) First sterno-pleural muscle (122).

The sterno-pleural muscle is small, arising on the base of the apodeme on which the anterior ventral transverse muscle (109) rises at the ventro-lateral intersegmental portion between the pro- and mesothorax, and is inserted into the anterior margin of the episternum (es).

2) Second sterno-pleural muscle (123).

The second sterno-pleural muscle is a small flattened bundle of fibers arising on the anterior lateral corner of the sternum, and inserted into the anterior portion of the episternum (es).

3) Sterno-basalar muscle or sternal pronator-extensor of the wing (124).

This is a broad and very strong muscle arising by a spreading base on the lateral wing of the basisternum, and inserted into the basalar plate (b). The ventral portion of the muscle is often subdivided into two or three bundles.

4) Dorsal furca-entopleural muscle (125). (Figs. 17 and 56).

The muscle is originated on the first less-thickened arm of the furca (fua 1), and inserted into the dorsal pleural arm (pami) projecting on the middle portion of the pleural ridge.

5) Ventral furca-entopleural muscle (126).

The muscle is slender, arising on the second or ventral less-thickened arm of the furca (fua 2), and inserted into the ventral pleural arm (pamii) on the coxacoila or pleural coxal process at the ventral end of the pleural ridge.

j. Muscles Connecting the Thorax with the Leg

These muscles include the bundles of fibers connecting the thorax with the coxa, trochanter and trochantin.

1) Tergal promotor of the coxa (127).

The muscle is very thick, arising by a somewhat wide base on the medio-lateral portion of the scutum (scu) at the posterior side of the first and second tergo-sternal muscles (112 and 113), and is inserted into a small apodeme on the median end of the trochantin (tn).

2) First tergal remotor of the coxa (128).

The remotor is a very thick muscle originating on the posterior lateral portion of the scutum (scu), and inserted into the posterior wall of the meron (m).

3) Second tergal remotor of the coxa (129).

The remotor is a stout bundle of fibers arising on the scutum (scu), and inserted into the latero-posterior wall of the meron (m), by the side of the first tergal remotor (128).

4) Third tergal remotor of the coxa (130).

The third muscle is slender, connecting dorsally with the posterior lateral portion of the scutum (scu) at the posterior side of the preceding muscle and, ventrally, with the posterior basal margin of the meron (m).

5) Anterior sternal promotor of the coxa (131).

This is a short muscle arising on the sternal median ridge at the anterior side of the furca (fu), and inserted into the anterior coxal basal rim at the median side of the portion with which the trochantin (tn) is articulated.

6) Posterior sternal remotor of the coxa (132).

This remotor is short, arising on the ventral surface of the furcal arm (fua), and inserted into the postero-median basal margin of the meron (m).

7) Pleural abductor of the coxa (133).

The abductor arises on the anepisternum (aes) at the anterior side of the first or dorsal pleural arm (pami), and is inserted into the antero-lateral base of the coxa.

8) Coxo-basalar muscle (134).

This is thick, originating on the dorsal portion of the basalare (b), and is inserted into the basicostal ridge of the coxa at the anterior side of the pleuro-coxal articulation.

9) Pleural promotor of the coxa (135).

This muscle is strong, arising on the basalare (b) immediately above the dorsal end of the sternal pronator extensor of the wing (124), and inserted into the middle portion of the trochantin (tn).

10) Coxo-subalar muscle (136).

This muscle is a broad and very strong bundle of fibers arising on the subalar invagination, and inserted into the postero-lateral portion of the meron (m) on the posterior side of the pleuro-coxal articulation. It is known as the coxal depressor extensor of the wing.

11) Tergal depressor of the trochanter (137).

The depressor is a very strong muscle arising by a broad base on the middle portion of the medio-lateral area of the scutum (scu), and inserted into a common strong depressor apodeme on the ventral base of the trochanter (trc).

12) Pleural depressor of the trochanter (138).

A thick muscle, originating on the dorsal portion of the episternum (es) at the dorso-posterior side of the basalare (b), and inserted into the common depressor apodeme of the trochanter (trc).

13) Sternal depressor of the trochanter (139).

The sternal depressor is smaller than the preceding depressors, it arises on the ventral surface of the furcal arm (fua) and is inserted into the common depressor apodeme of the trochanter (trc).

k. Leg Muscles Arising on the Leg Segments

(Figs. 30 and 45)

1) First levator of the trochanter (140).

The levator is a fan-shaped muscle arising on the anterior coxal wall, and inserted into a common levator apodeme on the dorsal base of the trochanter as in the fore leg.

2) Second levator of the trochanter (141).

This flattened muscle arises on the anterior lateral portion of the coxa near the proximal end of the first levator (140), and is inserted into the common levator apodeme on the dorsal base of the trochanter.

3) Third levator of the trochanter (142).

This levator is stronger than that of the fore leg, it arises on the posterior coxal wall at the distal side of the basicostal ridge, and is inserted into the common levator apodeme as the preceding muscle.

The fourth levator of the trochanter is lacking in the middle leg.

4) First coxal depressor of the trochanter (143).

The depressor is a very broadly fan-shaped muscle arising on the distal side of the anterior basicostal ridge of the coxa, and inserted into the common depressor apodeme on the ventral base of the trochanter.

5) Second coxal depressor of the trochanter (144).

This muscle which resembles that of the fore leg arises on the anterior-median wall of the coxa and is inserted into the basal portion of the common depressor apodeme of the trochanter.

6) Third coxal depressor of the trochanter (145).

The third depressor also resemles that of the fore leg, and arises on the postero-median wall of the coxa at the distal side of the basicostal ridge, and is inserted into the common depressor apodeme of the trochanter.

7) Reductor of the femur (146).

The muscle is very similar to that in the fore leg.

8) Levator of the tibia (147).

The tibial levator resembles that in the fore leg, but is smaller than that in the latter.

9) Depressor of the tibia (148).

This also resembles that in the fore leg, but the main branch is thinner and the two other branches are smaller than the corresponding branches in the fore leg.

10) Depressor of the tarsus (149).

The depressor is similar to that in the fore leg, but stronger than that in the latter.

11) Depressor of the pretarsus (150).

The muscle resembles that of the fore leg, but is a bundle of short fibers arising on the proximal ventral half of the tibia and inserted into the depressor apodeme along the long axis of the segment is added.

12) Ventral transverse muscles of the tarsus (151).

These are entirely similar to those of the fore leg.

C. MUSCLES OF THE METATHORAX

(Figs. 50-52, 56 and 57)

The muscles of the metathorax correspond to those of the mesothorax for according to the following comparison by numerical designation respectively: Dorsal muscles 152-156 to 102-106; ventral muscles 157-158 to 107-108; ventral transverse muscles 159-160 to 109-110; tergo-sternal muscles 161-163 to 111 113; tergo-pleural muscles 164-168 to 114-118; special wing muscle 169 to 119; pleural muscle 170 to 120; muscle of the spiracle 171 to 121; sterno-pleural muscles 172-176 to 122-126; muscles connecting the thorax with the leg 177-189 to 123-139; leg muscles arising on the leg segments 190-201 to 140-151. These muscles nearly resemble the corresponding muscles of the mesothorax respectively, but the occlusor of the second thoracic spiracle arises on the latero-anterior corner of the metasternum.

4. MUSCLES OF THE ABDOMEN

A. MUSCLES OF THE FIRST ABDOMINAL SEGMENT

(Figs. 50–52)

a. Posterior Protractor of the Crop and Gastric Caecum (203)

The posterior protractor is a very slender long muscle arising on the lateral portion of the anterior intersegmental ridge of the tergum, prolonged backward, divided into several fine branches at the end, some of the branches being attached on the crop and the others on the gastric caecum.

b. Dorsal Muscles

1) First internal dorsal muscle (204).

The first muscle is a median long flattened bundle of fibers arising on the anterior portion of the tergum immediately behind the third phragma (ph 3), and inserted posteriorly into the intersegmental thickening (act) between the first and second abdominal terga.

2) Second internal dorsal muscle (205).

The second is a medio-lateral longitudinal muscle resembling the preceding muscle, and originated and inserted on the side of the first muscle.

3) First external dorsal muscle (206).

The first external dorsal is a short median longitudinal muscle which is loosely bundled, arising on the middle portion of the median area of the anterior or main tergal plate and inserted into the median portion of the anterior margin of the posterior tergal plate (or the so-called precosta of the second abdominal tergum) (pc).

4) Second external dorsal muscle (207).

The second is a medio-lateral longitudinal muscle resembling the first external dorsal muscle, the origin and the insertion occuring at the side of the latter muscle.

5) Third external dorsal muscle (208).

The third muscle is a slender bundle of fibers arising on the anterior portion of the tergum (at) at the side of the anterior end of the second internal dorsal muscle (205), and inserted into the posterior tergal plate (pc) at the side of posterior end of the second external dorsal muscle.

6) First paratergal muscle (209).

The first muscle is oblique, longer than the preceding muscle, it arises on the lateral end of the third phragma (ph 3), and is inserted into the posterior tergal plate (pc) at the side of the third external dorsal muscle.

7) Second paratergal muscle (210).

The second is a strong oblique muscle arising on the side of the anterior end of the third external dorsal muscle, passing the outer side of the first paratergal muscle, and inserted into the lateral portion of the posterior tergal plate (pc).

c. Dorsal Transverse Muscles

1) Anterior dorsal transverse muscle (211).

The muscle is originated on the latero-median portion of the anterior intersegmental ridge of the tergum, diverging and inserted into the ventro-lateral portion of the dorsal blood vessel.

2) Posterior dorsal transverse muscle (212).

The muscle is originated on the latero-anterior portion of the posterior tergal plate (pc) between the posterior ends of the first and second paratergal muscles (209, 210), diverging and inserted into the ventro-lateral side of the dorsal blood vessel.

d. Ventral Muscles

1) First internal ventral muscle (213).

This is a median longitudinal muscle subdivided into two bundles, one (213a) originated on the basal postero-ventral face of the metafurcal arm (fua) and inserted into the intersegmental ridge (acs) on the posterior end of the sternum, the other (213b) arising on the metafurcal arm (fua) at the ventral side of the first bundle and inserted into the intersegmental ridge at the side of the first bundle.

2) Second internal ventral muscle (214).

The second muscle arises on the base of the apodeme (lsiap) of the anterior lateral corner of the sternum (as), and is inserted into the medio-lateral portion of the intersegmental ridge between the first and second sterna.

3) Third internal ventral muscle (215).

The third muscle is subdivided into two bundles, one (215a) arising on the metafurcal arm (fac) at the dorsal side of the first ventral muscle and inserted into the intersegmental ridge (acs) between the first and second abdominal sterna at the side of the preceding muscle, and the other (215b) attaching anteriorly to the apodeme (lsiap) of the antero-lateral corner of the sternum at the inner side of the second internal ventral muscle (214), and posteriorly to the intersegmental ridge at the side of the first bundle.

4) First external ventral muscle (216).

The muscle is oblique, short, arising on the middle portion of the medio-lateral region of the sternum, and inserted into the narrow posterior sternal plate (or the so-called sternal precosta of the second abdominal segment) (pcs) at the outer side of the second internal ventral muscle.

5) Second external ventral muscle (217).

The second muscle is an oblique long bundle of fibers arising on the metafurcal arm (fua) at the side of the first bundle (125a) of the third internal ventral muscle, and inserted into the lateral portion of the posterior sternal plate (pcs).

e. Ventral Transverse Muscle (218)

The transverse muscle is originated on the lateral portion of the posterior sternal plate (pcs), diverges, and joins in the formation of the common ventral net of ventral transverse muscles.

f. Tergo-Sternal Muscles

1) Posterior internal tergo-sternal muscle (219).

The tergo-sternal muscle is composed of several slender bundles of fibers connected with the lateral portion of the posterior of the tergum (pc) and the lateral end of the intersegmental area between the first and second abdominal sterna.

2) External intersegmental tergo-sternal muscle (220).

The muscle is an oblique bundle of fibers arising on the anterior portion of the posterior tergal plate at the side of the posterior end of the second paratergal muscle (210) and at the outer side of the internal tergo-sternal muscle (219), and is inserted into the antero-lateral corner of the second abdominal sternum.

g. Sterno-Pleural Muscle (221)

The sterno-pleural muscle is composed of small indefinite bundles of fibers arising on the antero-lateral corner of the sternum, and inserted into the lateral membrane.

h. Muscles of the Spiracle

1) Occlusor of the spiracle (222).

The occlusor is a short muscle arising on the ventral portion of the spiracle (sp), and inserted into the closing rod (cb) of the spiracle.

2) Ventral dilator of the spiracle (223).

The dilator is a small muscle arising on the antero-lateral corner of the sternum and inserted into the ventral portion of the spiracle at the ventral end of the preceding muscle.

3) Dorsal dilator of the spiracle (224).

The dorsal dilator is a small muscle arising on the lateral portion of the tergum at the dorsal side of the spiracle, and inserted into the dorsal face of the closing rod of the spiracle (sp).

i. Miscellaneous Lateral Muscles

On the pleural membrane there are very fine indefinite muscular fibers, some of which are stretched between the lateral portion of the tergum and the pleural membrane, and the others between the lateral portion of the sternum and the pleural membrane or the lateral portion of the tergum.

B. MUSCLES OF THE TYPICAL ABDOMINAL SEGMENTS

(Fig. 58)

The musculatures of the second to the sixth abdominal segment are nearly resembling one another as in the skeletal structures. They are generally accounted for in the present paper, and the figures are also desinated by common numerical signs.

a. Dorsal Muscles

1) First internal dorsal muscle (225).

The first internal dorsal muscle is a median longitudinal one resembling the first internal dorsal muscle of the first abdominal segment, it arises on the posterior side of the intersegmental ridge or so-called tergal antecosta (act) at the anterior end of the segment, and is inserted into the anterior side of the succeeded intersegmental ridge (act) at the posterior end of the segment.

2) Second internal dorsal muscle (226).

The second muscle is a medio-lateral longitudinal bundle of fibers resembling the preceding muscle. Origin and insertion both occurs on the anterior and posterior ends of the tergum at the side of the first muscle respectively.

3) First external dorsal muscle (227).

The first muscle is short, loosely bundled, arising on the middle portion of the medio-lateral region of the anterior main tergal plate, and inserted into the anterior margin of the posterior tergal plate (pc) near the median line.

4) Second external dorsal muscle (228).

The second is a short and loosely bundled muscle arising on the just posterior side of the anterior end of the preceding muscle, extending latero-posteriorly and inserted into the anterior end of the posterior tergal plate (pc) at the side of the first external dorsal muscle.

5) Third external dorsal muscle (229).

The third muscle somewhat resembles that of the first abdominal segment, arising on the anterior end of the tergum at the side of the second internal dorsal muscle, and inserted into the anterior portion of the posterior tergal plate (pc) at the outer side of the postero-lateral end in the second external dorsal muscle.

6) First paratergal muscle (230).

The first is a very long intersegmental muscle arising on the antero-lateral portion of the posterior tergal plate of the preceding segment immediately behind the posterior end of the second paratergal muscle in the preceding segment, and inserted into the side of the posterior end of the third external dorsal muscle.

7) Second paratergal muscle (231).

The second paratergal muscle is divided into four bundles, the first (231a) arises on the middle portion of the lateral of the anterior main tergal plate at the side of the first internal paratergal muscle, and is inserted into the anterior portion of the lateral of the posterior tergal plate (pc), the second bundle (231b) resembles the first bundle, but its origin and insertion occur more ventrally than those of the latter, the third bundle (231c) is long, arising on the lateral portion of the anterior end of the tergum, and is inserted into the lateral portion of the posterior tergal plate (pc) immediately ventral to the posterior end of the second bundle, the fourth bundle (231d) which is the longest of the four arises on the middle portion of the lateral region of the posterior tergal plate of the preceding segment, and is inserted into the posterior tergal plate (pc) immediately ventral to the posterior end of the third bundle.

b. Dorsal Transverse Muscles

The anterior and the posterior dorsal transverse muscles (232 and 253) of each typical abdominal segment are similar to those of the first abdominal segment respectively.

c. Ventral Muscles

1) First internal ventral muscle (234).

The first internal ventral muscle is a median longitudinal bundle of fibers arising on the sternal antecosta (acs), and inserted into the followed sternal antecosta (acs).

2) Second internal ventral muscle (235).

The second is an oblique slender muscle arising on the antero-lateral corner of the sternum, and inserted into the posterior sternal end (acs) at the side of the first internal ventral muscle.

3) Third internal ventral muscle (236).

The third is a medio-lateral longitudinal muscle arising on the anterior end of the sternum (acs) at the side of the first internal ventral muscle, extending to the posterior end of the sternum over the second internal ventral muscle, and inserted into the side of the latter muscle.

4) First external ventral muscle (237).

The first external ventral is a short and somewhat oblique muscle arising on the middle portion of the medio-lateral region of the sternum, and inserted into the posterior sternal plate (pcs) immediately anterior to the posterior ends of the second and third internal ventral muscles.

5) Second external ventral muscle (238).

The second muscle is short, oblique, arising on the side of the anterior end of the first external ventral muscle, and inserted into the lateral portion of the posterior sternal plate (pcs).

d. Ventral Transverse Muscles

The anterior and the posterior ventral transverse muscles (239 and 240) are nearly similar to the ventral transverse muscle of the first abdominal segment (218). The anterior muscle arises on the lateral portion of the intersegmental ridge at the anterior end of the sternum. The posterior muscle arises on the lateral portion of the posterior sternal division like the ventral transverse muscle in the first abdominal segment.

e. Tergo-Sternal Muscles

1) Anterior internal tergo-sternal muscle (241).

The muscle is slender, arising on the lateral portion of the anterior of the tergum and inserted into the lateral portion of the sternal intersegmental ridge at the anterior end of the segment.

2) Posterior internal tergo-sternal muscle (242).

The posterior internal tergo-sternal muscle is resemblant to that of the first abdominal segment.

3) External intersegmental tergo-sternal muscle (243).

This is an oblique, two-bundled muscle, the first bundle (243a) arises on the lateral portion of the posterior tergal plate immediately behind the posterior end of the first bundle of the second paratergal muscle (231a), the second bundle (243b) on the ventral side of the first bundle immediately behind the posterior end of the other bundles of the second paratergal muscle (231b–231d), and both are inserted into the latero-anterior corner of the sternum of the succeeded segment.

4) External tergo-sternal muscle (244).

The muscle is composed of several slender vertical bundles of fibers arising on the lateral portion of the anterior main tergal plate, passing the outer side of the paratergal muscles at the posterior side of the spiracle, and inserted into the lateral portion of the sternum.

f. Sterno-Pleural Muscle (245)

The sterno-pleural muscle is composed of several small bundles of fibers arising on the antero-lateral corner of the sternum, and inserted into the lateral membranous portion of the segment.

g. **Muscles of the Spiracle** (246-248)

The muscles of the spiracle in the typical abdominal segment are similar to those in the first abdominal segment.

h. **Miscellaneous Lateral Muscles**

The miscellaneous lateral muscles of the typical abdominal segment are also resemblant to those of the first abdominal segment.

C. MUSCLES OF THE SEVENTH ABDOMINAL SEGMENT IN THE FEMALE

(Fig. 59)

a. **Dorsal Muscles** (249-255)

The dorsal muscles in the seventh abdominal segment are nearly similar to those in the typical abdominal segment, but the third externol dorsal muscle is not extended to the anterior end of the tergum.

b. **Dorsal Transverse Muscles** (256-257)

The muscles are also resemblant to those in the typical abdominal segment.

c. **Ventral Muscles**

The seventh abdominal segment is provided with two ventral muscles as follows:

1) First ventral muscle (258).

The first ventral muscle is short, arising on the posterior portion of the medio-lateral of the sternum, and inserted into the posterior end of the oviduct.

2) Second ventral muscle (259).

The second muscle arises on the middle portion of the mediolateral region of the sternum, and is inserted into the posterior sternal plate (pcs) at the latero-posterior corner of the sternum. The muscle corresponds to the second external ventral muscle in the typical abdominal segment.

d. Ventral Transverse Muscles

1) Anterior ventral transverse muscle (260).

The muscle is similar to that in the typical abdominal segment.

2) Posterior ventral transverse muscle (261).

This muscle arising on the lateral portion of the posterior sternal plate (pcs) like that of the typical abdominal segment is prolonged forward along the median side of the oviduct, and joins in the formation of the common net of ventral transverse muscles.

e. Lateral Muscles and Muscles of the Spiracle (262-268)

The lateral muscles and the spiracular muscles of the seventh abdominal segment are resemblant to those in the typical abdomical segment.

D. MUSCLES OF THE EIGHTH ABDOMINAL SEGMENT OF THE FEMAEL

(Fig. 59)

a. Dorsal Muscles

The tergum lacks the paratergal muscles. The first and second internal dorsal muscles (269-270) resemble those of the typical abdominal segment. The first external dorsal muscle (271) also resembles that of the typical abdominal segment, but its posterior end attaches to the posterior end of the tergum immediately forward of the posterior end of the first internal dorsal muscle. The second external dorsal muscle (272) is situated more laterally than that in the typical abdominal segment and attached on the side of the posterior end of the second internal dorsal muscle.

b. Dorsal Transverse Muscle (273)

The dorsal transverse muscle corresponds to and resembles the anterior dorsal transverse muscle in the typical abdominal segment. but narrower.

c. Ventral Muscles

1) First sternal dilator of the vagina (274).

The dilator is a very loose bundle of fine fibers arising irregularly on the sternal median portion, and inserted into the ventral posterior portion of the vagina (v).

2) Second sternal dilator of the vagina (275).

This is a very broad muscle arising on the lateral portion of the sternum, inserted into the lateral portion of the vagina (v).

3) Third lateral dilator of the vagina (276).

The third dilator is a strong muscle arising on the lateral portion of the sternum at the posterior side of the second sternal dilator, and inserted into the posterior lateral portion of the vagina (v).

d. Ventral Transverse Muscle (277)

The muscle corresponds to the anterior ventral transverse muscle in the typical abdominal segment, it is very fine, arises on the lateral portion of the intersegmental ridge at the anterior end of the sternum, is associated with the posterior ventral transverse muscle of the seventh abdominal segment at the dorsal side of the posterior portion of the oviduct (ov), and joins in the formation of the common net of ventral transverse muscles.

e. Tergo-Sternal Muscles

1) Internal tergo-sternal muscle (278).

This is composed of three slender bundles arising on the antero-lateral region of the tergum and inserted into the antero-lateral portion of the sternum.

2) External tergo-sternal muscle (279).

The external tergo-sternal is a very slender muscle arising on the lateral portion of the eighth abdominal tergum, and inserted into the lateral portion of the eighth abdominal sternum across the outer side of the main lateral trachea at the anterior side of the spiracle.

f. **Muscles of the Spiracle** (280-282) and **Miscellaneous Lateral Muscles**

The muscles nearly resemble those in the typical abdominal segment.

E. MUSCLES OF THE NINTH ABDOMINAL SEGMENT IN THE FEMALE

(Fig. 59)

a. Dorsal Muscles

1) First and second internal dorsal muscles (283, 284).

The first and second internal dorsal muscles resemble those of the eighth abdominal segment respectively.

2) First external dorsal muscle (285).

This oblique muscle arises on the posterior margin of the anterior tergal plate at the side of the first internal dorsal muscle, and is inserted into the median portion of the anterior margin of the tenth abdominal tergal region.

3) Second external dorsal muscle (286).

The second muscle is small, oblique, situated on the side of the second internal dorsal muscle, attached anteriorly to the posterior margin of the anterior main tergal plate, and posteriorly to the anterior margin of the tenth abdominal tergal plate (at).

b. Dorsal Transverse Muscle (287)

This muscle which corresponds to the anterior dorsal transverse muscle in the typical abdominal segment is very slender, arises on the lateral portion of the anterior end of the tergum, and is inserted into the latero-ventral portion of the posterior terminal of the dorsal blood vessel.

c. Tergo-Sternal Muscles

1) First anterior internal tergo-sternal muscle (288).

A thick muscle, arising on the lateral portion of the ninth abdominal tergum, and inserted into the postero-lateral corner of the eighth abdominal sternum.

2) Second anterior internal tergo-sternal muscle or first lateral dilator of the vagina (289).

A thick intersegmental muscle arising on the lateral portion of the ninth abdominal tergum immediately above the dorsal end of the preceding muscle, and inserted into the side of the vagina (v).

3) Third anterior internal tergo-sternal muscle or second dilator of the vagina (290).

A strong intersegmental muscle arising on the posterior side of the first anterior internal muscle (288), and inserted into the side of the vagina (v).

4) First retractor of the genital lobe (291).

The first retractor arises on the postero-lateral portion of the ninth abdominal tergum, and is inserted into the middle portion of the basal margin of the genital lobe (gl).

5) Second retractor of the genital lobe (292).

The second is a muscle of which the origin and the insertion occur on the dorsal side of those of the first retractor respectively.

6) Posterior intersegmental tergo-sternal muscle (293).

This slender muscle arising on the posterior margin of the ninth abdominal tergum is inserted into the anterior portion of the so-called paraproct (pp).

F. DILATORS OF THE RECTUM AND ANUS OF THE FEMALE

The dilators consist of fine fibers arising on all the surface of the less-thickened proctiger, and attached irregularly on the rectum and anus.

G. MUSCLES OF THE SEVENTH ABDOMINAL SEGMENT OF THE MALE

The muscles are nearly similar to those of the typical abdomical segment.

H. MUSCLES OF THE EIGHTH ABDOMINAL SEGMENT OF THE MALE

(Fig. 28)

a. Dorsal Muscles

1) Internal dorsal muscle (294).

The internal dorsal muscle is longitudinal, strong, arising on the median portion of the anterior end of the tergum, and inserted into the anterior end of the ninth abdominal tergum near the median line.

2) External dorsal muscle (295).

This is very short, arising on the posterior portion of the tergum on the outer side of the internal dorsal muscle, and inserted into the anterior end of the ninth abdominal tergum immediately forward of the posterior end of the internal dorsal muscle.

b. Ventral Muscles

1) First ventral muscle (296).

This medio-lateral longitudinal muscle arising on the anterior portion of the sternum is inserted into the intersegmental membranous infolding between the eighth and ninth abdominal ventral regions.

2) Second ventral muscle (297).

This lateral longitudinal muscle arising on the anterior lateral portion of the sternum is inserted into the anterior lateral base of the penis hook (mlg 3). It may serve for the retractor of the penis hook.

c. Tergo-Sternal Muscles

1) First or anterior internal tergo-sternal muscle (298).

The muscle is very similar to that in the typical abdominal segment.

2) Second internal tergo-sternal muscle (299).

The internal tergo-sternal muscle is stout, vertical, attached dorsally to the lateral portion of the tergum and ventrally to the lateral portion of the sternum on the middle region of the segment.

d. Muscles of the Spiracle (300-302)

The spiracular muscles are nearly similar to those of the typical abdominal segment.

e. Miscellaneous Lateral Muscles

The miscellaneous lateral muscles also resemble those of the typical abdominal segment.

I. MUSCLES OF THE NINTH ABDOMINAL SEGMENT IN THE MALE

(Fig. 28)

a. Dorsal Muscles

1) Internal dorsal muscls (303).

The internal dorsal is a very stout longitudinal muscle arising on the anterior portion of the tergum near the median line, and inserted into the anterior margin of the tenth abdominal tergal plate or surgonopod (at, 10a).

2) External dorsal muscle (304).

The external dorsal is a strong longitudinal muscle arising on the middle portion of the medio-lateral region of the tergum at the outer side of the internal dorsal muscle, and inserted into the anterior end of the tenth abdominal tergal plate immediately forward of the posterior end of the internal dorsal muscle.

b. Ventral Muscles

1) First retractor of the second genital lobe (305).

This is an oblique muscle arising on the anterior lateral portion of the ninth abdominal sternal region, inserted into the medio-dorsal base of the second genital lobe (mlg 2) which projects as the dorsal lip of the genital opening.

2) Second retractor of the second genital lobe (306).

The second retractor which resembles the first retractor, arises on the latero-basal portion of the penis hook (mlg 3) more laterally than the first muscle, and is inserted into the medio-dorsal base of the second genital lobe (mlg 2).

c. Tergo-Sternal Muscles

1) Dorsal retractor of the third genital lobe (307).

The retractor is an anterior intersegmental tergo-sternal muscle arising on the lateral portion of the anterior intersegmental folding of the tergum, and inserted into the basal lateral portion of the penis hook or third genital lobe (mlg 3).

2) Tergo-sternal muscle (308).

This arises on the latero-median portion of the ninth abdominal tergum at the posterior side of the preceding muscle, and is inserted into a small latero-posterior sclerite of the ninth abdominal sternum (pnas).

3) Posterior intersegmental tergo-sternal muscle (309).

This strong muscle arising on the middle portion of the mediolateral region of the ninth abdominal tergum is inserted into the anterior portion of the paraproct (pp).

J. DILATORS OF THE RECTUM AND ANUS IN THE MALE (310)

(Fig. 28)

These muscles are resemblant to those in the female.

V. NERVOUS SYSTEM

i. CENTRAL NERVOUS SYSTEM

1. Brain and Its Nerves

(Figs. 5, 6, 9, 11)

The brain or supraoesophageal ganglion is situated in the median region of the head under the cranial dorsal wall on which three ocelli are arranged. It is divisible into three regions—the protocerebral, the deutcerebral and the tritocerebral. The protocerebral region is the largest dorsal part of the brain, which bears laterally a pair of large optic lobes, dorsally, a median ocellar pedicel and paired lateral ocellar pedicels (Mo, Lo), and posteriorly, a pair of nerves (La) connected with the visceral nervous system. The deutocerebral region is represented mainly as a pair of swellings or antennal lobes bearing the antennal nerves (Ar) under the protocerebral region. The tritocerebral region is represented mainly as a pair of lobes situated on the ventral side of the deutocerebral, giving off anteriorly a pair of frontal ganglion connectives (Fr) and a pair of labral nerves (L), and ventrally paraoesophageal connectives or crura cerebri (Pc) which unite the brain (B) with the suboesophageal ganglion (Sog).

The median ocellar pedicel (Mo) is very short, arising on the anterior median portion of the protocerebral region and bearing a conical enlargement at the apex. The lateral ocellar pedicels (Lo) are one-paired stalks, situated on the dorsal portion of the protocerebral region and very similar to the median ocellar pedicel.

The optic lobe is very thick, especially the middle portion, and bears a very large swelling at the apex.

The common root of the antennal nerves (Ar) is thick, arising on the top of the antennal lobe, giving off the nerve of the antennal depressor (Ad), the nerves of the antennal levators (Al) and the common nerve of the flagellar flexor and extensor (Af) at the basal dorsal portion. Moreover, after a short prolongation, the common root of the antennal nerves is divided at the scape (s) into two main branches, the first and the second antennal nerve (Ai, Aii).

The nerve of the antennal depressor (Ad) is slender, branched from the basal portion of the common root of the antennal nerves, extending laterally then ventrally, and then entering the antennal depressor muscle (6).

The nerves of the antennal levators (Al) are very small branches arising on the basal portion of the common root of the antennal nerves at the distal side of the nerve of the antennal depressor (Ad), and innervating the antennal levator muscles (4, 5).

The common nerve of the flagellar muscles (Af) arises on the medio-dorsal portion of the common root (Ar) of the antennal nerves near the nerves of the antennal levators (Al), and after a short prolongation it is divided into two branches, the nerve of the flagellar flexor (8) and the nerve of the flagellar extensor (7).

The first and second antennal nerves (Ai, Aii) are stout and long stems which extend to the apical segment of the antenna and supply branches to the pedicel (pd) and the flagellar segments (fl). The branches of the first antennal nerve are short, and enter the lateral walls of the segments by sub-branching. The branches of the second antennal nerve are longer than the former, especially in the male, and innervate the walls of the medio-ventral projections of the antennal segments.

The clypeo-labral or labral nerve (L) is arising on the tritocerebral region beneath the frontal ganglion connective or arched nerve (Fr), is divided into two branches (L1 and L2) at the posterior side of the first lateral dilator of the pharynx (45). The branch (L1) passes between the latter muscle (45), the retractor of the mouth angle (44) and the side of the dorsal dilators of the buccal cavity (38 and 39), and enters the labral wall after acceptance of a branch of the central nerve (C) of the median sympathetic system on the anterior side of the first dorsal dilator of the buccal cavity (38). The branch (L2) is prolonged medially around the anterior side of the retractor of the mouth angle (44), and divided into two portions, one of which is a stem of nerves entering the anterior and the posterior retractor of the labrum (2 and 3), while the other connects with the same branch of the other side.

The so-called postoesophageal commissure (Poc) belonging to the tritocerebral region is connected with the middle portion of the paraoesophageal connective (Pc) of both sides, supplying a pair of nerves to the first ventral pharyngeal dilators (49) which are incircled into a nervous ring formed by the brain, the paraoesophageal connectives and this commissure.

2. VENTRAL NERVE CORD

A. SUBOESOPHAGEAL GANGLION AND ITS NERVES

(Figs. 5, 6, 9, 11)

The suboesophageal ganglion (Sog) is a somewhat flattened spherical mass lying on the ventral portion of the head between the posterior arms of the tentorium (ptn). It is anteriorly connected with the supraoesophageal ganglion by the paraoesophageal connectives or crura cerebri (Pc), and posteriorly with the first thoracic ganglion by the long connectives; moreover it gives off antero-ventrally three pairs of nervous roots, the mandibular (M), the maxillary (Ma) and the anterior labial nervous roots (Lb), latero-posteriorly, a pair of posterior labial nervous roots (So), and posteriorly, a median nerve (Mn).

The mandibular nervous root (M) is thick, arising on the anterior portion of the suboesophageal ganglion (Sog) at the latero-ventral side of the paraoesophageal connective (Pc), extending to the base of the mandible after running between the maxillary muscles arising on the tentorium (tnb) and the adductor apodeme of the mandible (ap 10). It is divided into four branches: the first (M 1) is the largest of the four, extends to the head cavity, and enters the dorsal adductor of the mandible by sub-branching; the second (M 2) is thick, passing the side of the first branch (M 1), and entering the abductor of the mandible in the head cavity; the third branch (M 3) is small, subdivided into two branches, one of which enters the ventral abductor, the other innervates the mandibular wall by subdividing; the fourth (M 4) is a very slender nerve which enters the lateral portion of the clypeal wall (cl).

The root of the maxillary nerves (Ma) arises on the anterior portion of the suboesophageal ganglion (Sog) at the ventral side of the root of mandibular nerves (M), and is divided into three main branches, the first (Ma i), the second (Ma ii) and the third (Ma iii) at the base of the maxilla.

The first branch (Ma i) of the maxillary nerves is divided into two, one of which (Mai 1) is subdivided into the nerve of the adductors of the cardo (Mai 1c) and the nerve of the adductor of the stipes (Mai 1s), and the other (Mai 2) is also subdivided into two at the basal portion of the maxilla, the nerve of the levator of the maxillary palpus (Mai 2p) and the branch extending to the head cavity along the cranial flexor of the stipes (15) and breaking up the nerve of the latter flexor of the stipes (Mai 2s) and the nerve of the promotor of the cardo (Mai 2c).

The second branch of the maxillary nerves (Ma ii) extends to the stipes after running between the adductor of the stipes and the adductor of the cardo, and is divided into two branches, one of which is a common branch of nerves of the stipital flexor of the lacinia and the flexor of the galea (Maiis and Maiig), the other is a common branch of nerves of the levator of the maxillary palpus and the depressor of the same palpus (Maiipl, Maiipd).

The third branch of the maxillary nerves (Maiii) is a nerve passing between the adductor of the stipes (14) and the cranial flexor of the stipes (15), then prolonged distally, and giving off three sub-branches:—the nerve of the lacinial wall (Maiii 1), the nerve of the galeal wall (Maiiig) and the main nerve of the maxillary palpus (Maiiip). The first (Maiii 1) is slender, branched from the main nerve (Maiii) at the proximal portion of the stipes, and entering the lacinial wall (1c); the second (Maiiig) is divided from the main branch (Maiii) at the base of the maxillary palpus and enters the galea by branching; the third (Maiiip) is a terminal long branch of the main nerve (Miii), entering the maxillary palpus and supplying fine nerves to the muscles and the wall of the palpus.

The root of the anterior labial nerves (Lb) which is more slender than each of those of the mandibular and the maxillary nerves, arises on the suboesophageal ganglion (Sog) at the ventral side of the root of the maxillary nerves (Ma), and is prolonged forward for a short distance, and divided into two main branches (Lba and Lbb). The first main branch (Lba) is extended forward and gives off two branches, the nerve (Lba 1) of the median retractor of the mentum (29) and the nerve (Lba 2) of the median retractor of the prementum (30). The second main branch (Lbb) is stouter than the first, entering the wall of the ligula (1g) by the distal branch (Lbb 4), and giving off three branches (Lbb 1, Lbb 2, Lbb 3) on the way. The first (Lbb 1) arises on the middle portion of the main branch and innervates the lateral retractor of the prementum (31), the second (Lbb 2) is thick, branches from the main nerve at the posterior side of the dorsal dilator of the common salivary duct (35) and enters the labial palpus, and the third (Lbb 3) is a small stem of nerves which enter the extensor of the labial pulpus (32) and the ventral dilators of the common salivary duct (36 and 37) by sub-branching.

The posterior labial nerve (So) arising on the lateral side of the suboesophageal ganglion (Sog) is prolonged backward, and divided into two branches at the gulamentum (gum); one branch (So 1) enters the proximal portion of the retractor of the hypopharynx (28), the other extends to the posterior end of the head and subdivided into two, the nerve of the postoccipital wall (So 2) and the nerve of the salivary gland (So 3), the latter nerve connecting with a fine nerve of the prothorax.

B. PROTHORACIC GANGLION AND NERVES

(Figs. 7, 11, 48, 49)

The prothoracic nerves branch off from three pairs of roots of nerves, one pair of which (I) arise on the connectives connecting the suboesophageal ganglion (Sog) with the prothoracic ganglion (G), and two others (II and III) arise on the prothoracic ganglion.

a. **Prothoracic Ganglion** (G)

The prothoracic ganglion is a large roundish and somewhat flattened mass anteriorly connected with the suboesophageal ganglion (Sog) by a pair of long connectives, and posteriorly with the ganglion (G) of the mesothorax by a pair of connectives. It gives off laterally two pairs of roots of the main nerves (III and IV), and posteriorly a median nerve (Mn).

b. **First Root of the Nerves** (I)

This root is a nerve arising on the connective at the anterior side of the prothoracic ganglion. It is divided into two branches, the first (Ia) is a common stem of nerves of the dorsal muscles, the second (Ib) is a commion branch of nerves of the ventral longitudinal muscles. The first stem (Ia) runs upward, giving off a slender branch (Ia 2) which enters the first and second internal tergo-sternal muscles (65, 66) and connects with the transverse nerve (Tn) at the side of the ventral longitudinal muscle (61). Moreover the first stem (Ia) breaks up into two branches, the first (Ia 5i) and the second (Ia 5ii), at the median side of the internal tergo-sternal muscles (65, 66). The first branch (Ia 5i) is subdivided into several threads, some of which enter the second internal dorsal and the first external dorsal muscle (54, 56), while the others are prolonged backward to enter the second external dorsol and the paratergal muscle (57 and 58); the second branch (Ia 5ii) gives off the nerve of the first internal dorsal muscle (Ia 5iia) and the nerves of the protergal muscles of the head (Ia 5iib), and often connects with the posterior slender branch of the nerve (So) of the suboesophageal ganglion (Sog).

c. **Second Root of the Nerves** (II)

This root is a short common base of prothoracic nerves mainly entering the lateral region of the segment and the leg. It arises on the latero-anterior portion of the prothoracic ganglion (G) and is divided into four branches, one to four (IIa–IId), at the antero-lateral side of the same ganglion.

The first branch (IIa) is a very slender nerve which enters the anterior portion of the main prosternal plate.

The second branch (IIb) is a stout common stem of nerves, divided into two branches (IIba and IIbb). The first nerve (IIba) is subdivided into five branches (IIba 1–IIba 5):—the first (IIba 1) is a slender nerve entering the first sternal promotor of the coxa (84); the second (IIba 2) is long, slender, entering the third external intersegmental tergo-sternal muscle (71); the third (IIba 3) passing the side of the first external tergo-sternal muscle, is antero-laterally prolonged to supply branches to the second external tergo-sternal muscle, the first, the second and the third tergo-pleural muscle (73–75); the fourth (IIba 4) is short and innervates the sternal wall and the anterior intersegmental tergo-furcal muscle (67); the fifth (IIba 5) enters the pleural abductor of the coxa (87). The second nerve (IIbb) is also subdivided into five branches (IIbb 1–IIbb 5); branch (IIbb 1) gives off two nerves, one entering the second and third internal tergo sternal muscles by subdivision, the other entering the first and second external intersegmental tergo-sternal muscles (69, 70) after forward prolongation; branch (IIbb 2) is divided into two threads, anterior and posterior, the anterior thread supplies nerves to the anterior membrane and the anterior lateral wall of the protergum (pt) by subdivision, and the posterior thread enters the lateral portion of the protergal wall;

branch (IIbb 3) runs upwards between the second and third internal tergo-sternal muscles, and is subdivided into two threads, one of which enters the lateral portion of the protergal wall at the dorsal side of the first internal tergo-sternal muscle (64), and the other also enters the protergal wall at the median side of the dorsal end of the first tergal promotor of the coxa (80); branch (IIbb 4) is prolonged backward to enter the posterior protergal wall, and branch (IIbb 5) is short, innervating the first and second tergal promotors of the coxa (80 and 81).

The third branch (IIc) is a leg nerve arising on the posterior face of the second root (II) of the prothoracic nerves at the anterior side of the coxa, is divided into two branches, the nerve of the anterior sternal promotor of the coxa (IIc 1) and the nerve of the furcal depressor of the trochanter (IIc 2), the latter is thicker than the former and enters the furcal depressor of the trochanter (88) from the anterior side, while the former nerve (IIc 1) is slender and enters the second sternal promotor of the coxa (85) from the dorsal side.

The fourth branch (IId) is a leg nerve arising on the second common root of the prothoracic nerves (II) at the side of the third branch (IIc), entering the coxal segment from the side and extending to the trochanter. It gives off seven branches :—the nerve of the sternal wall (IId 1), the nerve of the pleural wall (IId 2), the nerve of the pleural abductor (IId 3), the nerve of the first trochanteral levator (IId 5), the nerve of the levator apodeme of the trochanter (IId 6), and the distal branch (IId 7) connecting with the nerve (IIIb). The nerve of the sternal wall (IId 1) is slender, arising on the basal portion of this common branch (IId) and innervating the sternal wall. The nerve of the pleural wall (IId 2) is also slender, separated from the common stem (IId) at the lateral basal portion of the coxa, and enters the pleural membrane over the posterior portion of the first tergo-pleural muscle (76). The nerve of the pleural abductor of the coxa (IId 3) is a slender branch arising on the common stem (IId) at the distal side of the preceding nerve, and enters the pleural abductor of the coxa (86) near the coxal base. The nerve of the first trochanteral levator (IId 5) branches from the main stem (IId) at the lateral middle portion of the coxa and enters the first levator of the trochanter (89) from the latero-posterior side of the latter muscle. The nerve of the levator apodeme of the trochanter (IId 6) is slender, branching from the distal side of the preceding and entering the basal portion of the common apodeme of the trochanteral levators. The distal nerve (IId 7) is prolonged downwards and connected with the nerve (IIIb) in the trochanter.

d. Third Root of the Nerves (III)

The third root (III) is a stout common base of the nerves of the lateral muscles, the leg muscles and the body wall. It arises on the lateral portion of the prothoracic ganglion (G), and is divided into two main branches of leg nerves, one (IIIa) of which is a posterior common stem of the nerves of the lateral, coxal and trochanteral muscles and the body wall, and the other (IIIb) is the large stem of the leg nerves.

The posterior coxal branch (IIIa) is divided into three branches (IIIa 1, IIIa 2 and IIIa 3) at the medio-posterior base of the coxa. The first branch (IIIa 1) is a small nerve entering the posterior sternal remotor (86). The second branch (IIIa 2) is thick, extending to the lateral side of the coxa along the posterior basal margin of the coxa, and giving off three branches, the nerve of the tergal remotor of the coxa (IIIa 2iia), the nerve of the fourth tergo-pleural muscle (IIIa2ic), and the never of the latero-posterior protergal wall (IIIa 2iib). The third branch (IIIa 3) is laterally prolonged and divided into two branches, one of which (IIIa 3iic) enters the pleural remotor of the coxa (83), the other (IIIa 3iii) is prolonged downward and subdivided into two nerves, the nerve of the second levator of the trochanter (IIIa 3iiia) and the nerve of the third and fourth levators of the trochanter (IIIa 3iiib).

The main stem of the leg nerves (IIIb) (see Figs. 7, 29) is thick, long, entering the coxal segment from the median side of the coxal base, and extending to the distal end of the leg. It supplies three nerves

(IIIb 1–IIIb 3) to the coxal segment; the first (IIIb 1) is a very small basal branch which enters the second sternal promotor (85), the second (IIIb 2) arises on the same stem (IIIb) near the first nerve and enters the coxal wall, and the third (IIIb 3) is a nerve branching from the median face of the main stem (IIIb) at the distal side of the second, and subdivided into three branches:—the nerve of the first coxal depressor of the trochanter (IIIb 3i), the nerve of the second coxal depressor of the trochanter (IIIb 3ii) and the nerve of the third coxal depressor of the trochanter (IIIb 3iii).

Furthermore the main stem (IIIb) gives off two branches, the trochanteral nerve (IIIb 4) and the nerve of the tibial levator (IIIb 5), in the trochanter, then breaks up into two main long nerves, the nerve (IIIb 6a) and the nerve (IIIb 6b), at the basal portion of the femur. The trochanteral nerve (IIIb 4) is thick but short and supplies fine branches to the reductor of the femur (97) and the trochanteral wall. The nerve of the tibial levator (IIIb 5) is long, prolonged along the dorsal side of the femur, and enters the levator muscle of the tibia (95). The nerve (IIIb 6a) extends to the distal end of the leg, and supplies fine branches to the depressor of the tibia (98), the depressor of the pretarsus (100), the depressor of the tarsus (99), the ventral transverse muscles of the tarsus (101), and to the femoral, the tibial, the tarsal and the pretarsal wall. The nerve (IIIb 6b) resembles to the preceding one, extending to the distal end of the leg, and supplying fine branches to the depressor of the pretarsus (100), the depressor of the tarsus (99), and the ventral transverse muscles of the tarsus (101).

C. MESOTHORACIC GANGLION AND NERVES

(Figs. 8, 18, 50, 52, 56)

The mesothoracic innervation is very different from the prothoracic. The mesothoracic nerves branch from four pairs of main branches (I–IV), of which the first (I) arises on the connectives, and the second to the fourth (II—IV) on the mesothoracic ganglion.

The first to the third main branch (I, II, III) probably correspond to the first to the third main root in the prothorax respectively, but the fourth root (IV) is a common wing nerve lacking in the prothorax.

a. Mesothoracic Ganglion (G)

The ganglion resembles that of the prothorax, anteriorly connected with the prothoracic ganglion by a pair of connectives, posteriorly with the metathoracic ganglion by a pair of connectives, and laterally giving off three pairs of main nervous roots (II-IV) and posteriorly a median nerve (Mn).

b. First Root of the Nerves (I)

The first root of the nerves is very thick, arising on the connective at the anterior side of the mesothoracic ganglion, and divided into two main stems, (Ia) and (Ib).

The first stem (Ia) extends to the dorsal region of the body along the median side of the tergo-sternal muscles (112, 113). The basal portion of the stem is provided with a nerve (Ia 2) entering the lateral muscles, and the distal portion of the stem becomes a common stem of nerves of dorsal muscles (Ia 5). The nerve of the lateral muscles (Ia 2) is slender, arising from the first main stem (Ia) at the ventral side of the ventral muscle (107), and runs laterally, supplying fine nerves to the sterno-pleural muscle (122) and the spiracular muscle (121), and is connected with the lateral or transverse branch (Tn) of the median nerve (Mn) at the ventral side of the spiracle; moreover it is prolonged forward and enters the posterior intersegmental tergo-furcal muscle of the prothorax (68). The common nervous stem of the dorsal muscles (Ia 5) gives off four main nerves. The first nerve of the dorsal muscles branches from the dorsal portion of the main stem (Ia 5) at the ventral side of the middle portion of the second internal dorsal muscle, and is divided into two branches after a short prolongation, one is prolonged forward entering the second and third internal dorsal muscles (103, 104) by subdivision, the other is prolonged backward innervating the second internal dorsal and second external dorsal muscles (103, 106) by subdivision. The second nerve of the dorsal muscles is slender, divided from the main stem (Ia 5) at the median side of the middle portion of the internal dorsal muscles, prolonged backward, and enters the first internal dorsal muscle (102). The third nerve of the dorsal muscles is an anterior branch on the end of the main stem (Ia 5), and enters the first internal dorsal muscle (102). The fourth nerve of the dorsal muscles is a posterior branch on the end of the main stem (Ia 5), and enters the first external dorsal muscle (105) through the first internal darsal muscle.

The second main stem (Ib) is a stout nerve of the main root (I), not so long as the first main stem (Ia), it enters the ventral longitudinal muscle (107).

c. Second Root of the Nerves (II)

(Figs. 50, 51)

The second root of the nerves is thick, divided into four main stems:—(IIa), (IIb), (IIc) and (IId), at the side of the mesothoracic ganglion (G).

The first stem (IIa) is very slender, arising on the antero-ventral portion of the base of the main root (II) and prolonged downwards and entering the sternal wall by subdivision.

The second stem of the second root (IIb) is thick, divided into three branches:—(IIb 1), (IIb 2) and (IIb 3), at the side of the ventral longitudinal muscle (107).

The first nerve (IIb 1) is a slender branch extending forward and then curved backward around the anterior side of the sternal pronator-extensor of the wing (124), and entering the pleural wall.

The second branch (IIb 2) is thick and divided into three main nerves (IIb 2i, IIb 2ii and IIb 2iii). The first (IIb 2i) is a basal short nerve entering the first tergo-sternal muscle (112). The second nerve (IIb 2ii) is thick, prolonged upward, divided into two branches, one

(IIb 2iia) of which is prolonged backward, entering the tergal promotor of the coxa (127) and giving off a nerve (IIb 2iib) which enters the trachea at the median side of the dorsal end ot the tergal promotor of the coxa (127), the other branch (IIb 2iic) is prolonged upward and divided into two branches:--the nerve (IIb 2iic 1) of the second tergo-sternal muscle (113) and the nerve (IIb 2iic 2) connecting with the nerve of the tergo-pleural muscles (IIb 2iii). The third nerve (IIb 2iii) is slender, antero-dorsally prolonged and entering the first, second and third tergo-pleural muscles (114, 115 and 116).

The third branch (IIb 3) is thick, prolonged forward, then curved dorso-posteriorly between the tergo-sternal muscles (112, 113) and the coxo-basalar muscle (134) around the anterior side of the tergo-sternal muscles, and giving off a nerve (IIb 3i) divided into three, viz.:—the nerve of the pleural promotor of the coxa (IIb 3ia), the nerve of the pleural abductor of the coxa (IIb 3ib) and the nerve of the sternal pronator-extensor of the wing (IIb 3ic), at the side of the pleural promotor of the coxa (135) and the pleural depressor of the trochanter (138). Furthermore the third branch (IIb 3) gives off a slender nerve (IIb 3ii) connected with the nerve (IIb 2iib) at the median side of the coxo-basalar muscle (134), and the nerve of the fourth tergo-pleural muscle (IIb 3iii) at the dorsal side of the former nerve, and is often prolonged upward to connect with the nerve of the tergo-pleural muscles (IIb 2iii) and the nerve of the pleuro-axillary muscle (IIIa 2id) by two slender branches (IIb 3iv and IIb 3v).

The third stem (IIc) of the second root (II) extends backward, and divides into two branches, one of which is the nerve entering the furcal depressor of the trochanter (IIc 2) from the anterior side, while the other is curved laterally, and subdivided into two nerves (IIc 3, IIc 4) entering the pleural depressor of the trochanter and the tergal depressor of the trochanter respectively.

The fourth stem (IId) of the second root (II) branches from the basal portion of the third stem (IIc), is prolonged laterally between the first tergo-sternal muscle (112) and the tergal promotor of the coxa (127), and enters the coxal segment at the side of the pleural and tergal depressors of the trochanter (138, 137) round the anterior side of the these depressors. It gives off two branches:—the nerve of the coxal wall (IId 4), which enters the latero-basal coxal wall at the side of the pleural and tergal depressors of the trochanter, and the nerve of the first levator of the trochanter (IId 5) at the central portion of the latero-anterior side of the coxa, and its distal end connects with the nerve (IIIb) at the basal portion of the trochanter.

d. **Third Root of the Nerves** (III)

(Fig. 28)

The third root gives off two main stems, the posterior coxal stem (IIIa) and the main leg stem (IIIb) as in the prothorax, but is very much shorter than that in the prothorax.

The first nervous stem (IIIa) is thick, prolonged laterally, and divided into three branches—the nerve of the posterior sternal remotor of the coxa (IIIa 1) and the coxal nerves (IIIa 2 and IIIa 3).

The nerve of the posterior sternal remotor of the coxa (IIIa 1) is slender, prolonged medially, and enters the posterior sternal remotor of the coxa (132).

The nerve (IIIa 2) is long, prolonged laterally, and divided into two branches, (IIIa 2i and IIIa 2ii), at the side of the intersegmental tergo-furcal muscle (111). The first branch (IIIa 2i) prolonged forward between the second and third tergal remotors of the coxa (129, 130) and the coxo-subalar muscle (136) around the posterior portion of the third tergal remotor of the coxa (130), extends to the wing base, giving off:—the nerve of the coxo-subalar muscle (IIIa 2ia) at the posterior portion of the segment, the tracheal nerve (IIIa 2ib) at the side of the first tergal remotor of the coxa, and the nerve of the fifth tergo-pleural musble (IIIa 2ic) at the anterior side of the latter nerve, and terminates in the nerve of the pleuro-axillary muscle (IIIa 2id) at the wing base. The second branch (IIIa 2ii) is subdivided into three, viz. the nerves of the first, second and third tergal remotors of the coxa (IIIa 2iia1, IIIa2iia 2 and IIIa 2iia 3).

The nerve (IIIa 3) is divided into four branches:—the nerve of the furca-entopleural muscles (IIIa 3i), the nerve of the coxo-subalar muscle (IIIa 3iia), the nerve of the tergal remotor of the coxa (IIIa 3iib), and the nerve of the trochanteral levator (IIIa 3iii). The first (IIIa 3i) is slender, divided from the main branch (IIIa 3) at the posterior side of the thoracic trochanteral depressors (137–139), prolonged laterally then anteriorly around the side of these muscles, and enters the dorsal and ventral furca-entopleural muscles (125, 126) by subdivision. The second and third nerves (IIIa 3iia and IIIa 3iib) branch from their common nerve divided from the end of the main stem (IIIa 3) with the nerve of the trochanteral levators (IIIa 3iii); the second nerve (IIIa 3iiia) is an anterior branch entering the ventral portion of the coxo-subalar muscle (136), and the third nerve (IIIa 3iib) is a posterior slender branch innervating the ventral portion of the first tergal remotor of the coxa (128). The fourth nerve (IIIa 3iii) is prolonged downward and divided into two, the nerve of the second levator of the trochanter (IIIa 3iiia) and the nerve of the third levator of the trochanter (IIIa 3iiib).

The main stem (IIIb) of the leg nerves is very thick, long and very similar to that in the fore leg.

e. Fourth Root of the Nerves (IV)

The fourth root is thick, arising on the latero-anterior portion of the ganglion, prolonged upward along the anterior side of the tergo-sternal muscles, passing the side of the first and second tergo-pleural muscles and then entering the wing. After giving off a proximal branch (IVa) entering the pleural membrane at the ventral side of the spiracle, the fourth root is divided into two branches, the anterior (IVb) and the posterior (IVc), at the posterior side of the first thoracic spiracle. The anterior branch (IVb) gives off the nerve of the tegula (IVb 1) which enters the tegulal wall (tg) by numerous sub-branches, the costal nerve (IVb 2i) and the subcostal nerve (IVb 2ii) which extend along the costal and subcostal veins respectively. The posterior nerve (IVc) is divided into two small stems, the anterior (IVc 1) and the posterior (IVc 2), the anterior stem (IVc 1) is subdivided into the radial nerve (IVc 1i) and the median nerve (IVc 1ii) which are prolonged along the radial vein and the medial vein respectively, while the posterior branch (IVc 2) is divided into the cubital nerve (IVc 2i) and four anal nerves (IVc 2ii-IVc 2v) which are extended along the cubital and the anal veins respectively.

D. MESOTHORACIC GANGLION AND NERVES

(Figs, 29, 50, 52 and 56)

The metathoracic innervation in the central nervous system resembles that of the mesothorax.

E. GANGLION AND NERVES OF THE FIRST ABDOMINAL SEGMENT

(Fig. 50)

The first abdominal segment is innervated from three pairs of main roots of nerves arising on the lateral side of the first abdominal ganglion.

a. Ganglion

The ganglion is smaller than that of the thorax, roundish, somewhat flattened, situated on the posterior side of the furca of the metathorax, connected anteriorly with the metathoracic ganglion by a pair of connectives, and posteriorly with the ganglion of the second abdominal segment by a median nerve and one-paired connectives.

b. First Root of the Nerves (Ia)

The first root (Ia) is thick, arising on the lateral portion of the ganglion, passing tbe ventral side of the first internal ventral muscle (213), the median half of the third internal ventral muscle (215a) and the second externai ventral muscle (217), then extending to the dorsal area of the segment along the side of the segment. It gives off a nervous stem the lateral muscles (Ia 2) and a nervous stem of the dorsal muscles (Ia 5). The nervous stem of the lateral muscles (Ia 2) is divided from the main root (Ia) at the lateral portion of the sternum, supplying branches to the sterno-pleural muscles (221), the dilator and occlusor muscles of the first abdominal spiracle (222–224) and the lateral portion of the tergal intersegmental ridge, at the ventral side of the spiracle, moreover it extends forward to enter the intersegmental tergo-furcal muscle of the metathorax (163) after acceptance of a connection with the slender transverse nerve (Tn). The nervous stem of the dorsal muscles (Ia 5) gives off three branches, the first nerve of which branches from the dorsal portion of the main stem (Ia 5) at the lateral portion of the tergum and enters the third external dorsal muscle and the paratergal muscles (208–210) by subdivision; the second nerve branches from the dorsal portion of the main branch (Ia 5) at the ventral side of the second internal dorsal muscle (205) and entering the latter muscle (205) and the first and second external dorsal muscles (206–207); the third nerve is a dorsal branch of the main nerve (Ia 5) and innervates the first internal dorsal muscle (204).

c. Second Root of the Nerves (Ib)

The second root (Ib) is the common nerve of the ventral muscles. It gives off three main branches, the first (Ib 1) of which is a basal branch entering the first vental muscles (213a-213b), the second (Ib2) is a posterior terminal branch of the main nerve (Ib) entering the second internal ventral muscle (214) and the median half of the third internal ventral muscle (215a), and the third (Ib 3) is an anterior terminal branch of the main nerve (Ib) and enters the lateral half of the third internal ventral muscle (215b) and the second external ventral muscle (217).

d. Third Root of the Nerves ($\dot{V}$)

The root (V) is slender, arising on the ganglion at the postero-ventral side of the second root (Ib), passing the under side of the first internal ventral muscles (213) and the third internal ventral muscles (215), extending to the latero-posterior region of the segment, and divided into two, the nerve of the first external ventral muscle (Vb) and the common nervous stem (Vd) of the second external ventral muscle (Vd 1), the nerve of the lateral wall (Vd 2) and the nerve of the external intersegmental tergo-sternal muscle (Vd 3), at the medio-lateral region of the sternum. The nerve of the second external ventral muscle (Vd 1) is very small, divided from the common nervous stem (Vd) at the latero-posterior region of the sternum, and enters the posterior portion of the second external ventral muscle (218). The nerve of the lateral wall (Vd 2) and the nerve of the external intersegmental tergo-sternal muscle (Vd 3) branch from the common stem (Vd) at the lateral region of the segment, the former extending forward and entering the lateral wall by sub-branching, and the latter being prolonged backward at the side of the posterior internal tergo-sternal muscle (219), and entering the external intersegmental tergo-sternal muscle (220).

F. GANGLIA AND NERVES OF THE TYPICAL ABDOMINAL SEGMENTS

(Fig. 58)

a. Ganglions (G)

The ganglion in each of the second to the sixth uniform abdominal segmont is situated on the anterior portion of the sternum, resembling that of the first abdominal segment in shape, and slightly smaller than that of the thorax, but slightly larger than that of the first abdominal segment.

b. First Root of the Nerves (I)

The first root of the nerves (I) is thick, arising on the lateral middle portion of the ganglion, and is divided into two main stems at the side of the ganglion, one (Ia) of which is a thick and long stem, corresponding to the first nervous root in the first abdominal segment, the other (Ib) is a thick but short stem corresponding to the second nervous root in the first abdominal segment.

The first main stem of nerves (Ia) gives off small stems (Ia 1–Ia 5).

The first stem (Ia 1) is a small nerve arising on the basal portion of the main nerve (Ia), prolonged latero-anteriorly and entering the lateral portion of the sternal intersegmental ridge by fine sub-branches.

The second stem (Ia 2) branches from the main stem (Ia) at the medio-lateral portion of the anterior sternal region, is divided into two branches, one (Ia 2i) of which is prolonged towards the antero-lateral corner of the sternum, giving off the nerve of the tergo-pleural muscle (245), the nerves of the dilators and occlusor of the spiracle (246–248), and the nerves of the anterior internal intersegmental tergo-sternal muscles (241), connected with the transverse branch (Tn) of the median nerve (Mn), then entering the posterior internal intersegmental tergo-sternal muscle (219 or 242) in the preceding segment and often connected with the nerve of the external intersegmental tergo-sternal muscle (220 or 243) of the preceded segment; the other (Ia 2ii) is prolonged laterally at the posterior side of the first branch (Ia 2i) entering the pleural wall through the anterior and posterior sub-branches.

The third stem (Ia 3) branches from the main stem (Ia) at the ventral side of the spiracle and is divided after a short prolongation into two—the anterior branch (Ia 3i) and the posterior branch (Ia 3ii). The anterior branch (Ia 3i) is antero-dorsally prolonged at the side of the trachea and the first paratergal muscle (230), and supplying a small nerve to the lateral portion of the posterior tergal plate of the preceding segment (or so-called precosta), and further extending medially to enter the wall of the same posterior tergal plate at the side of the median line. The posterior branch (Ia 3ii) is short, dorsally prolonged round the posterior side of the spiracle (sp), and entering the tergal wall at the dorsal side of the spiracle (sp).

The fourth stem (Ia 4) branches from the main stem (Ia) at the median side of the spiracle, passing the lateral side of the first paratergal muscle (230) and two lateral bundles of the second paratergal muscle (231), and extending dorsally and enters the lateral tergal wall by two sub-branches, the anterior and the posterior.

The fifth stem (Ia 5) is a large nerve giving off three branches, the first to the third. The first branch is short, divided from the stem (Ia 5) at the dorsol side of the fourth stem (Ia 4), and supplying branches to the first paratergal muscle (230) and the second paratergal muscle (231). The second branch is divided from the stem (Ia 5) at the ventral side of the second internal dorsal muscle (226), innervating the latter muscle and the first and second external dorsal muscles (227, 228) by sub-branches. The third is an apical branch of the stem (Ia 5) entering the first internal dorsal muscle (225).

The second main stem of nerves (Ib) is thick, but short, giving off three nerves, (Ib 1), (Ib 2) and (Ib 3). The first (Ib 1) is a basal branch which enters the first internal ventral muscle (234) by subdivision. The second (Ib 2) branches from the main stem (Ib) at the side of the first nerve (Ib 1), prolonged backward, and supplying branches to the second internal ventral muscle (235), the third internal ventral muscle (236) and the second external ventral muscle (238). The third nerve (Ib 3) is short, but thick, entering the third internal ventral muscle (236).

c. Second Root of the Nerves (V)

The second root (V) arises on the latero-ventral side of the ganglion, prolonged latero-posteriorly, and gives off four main stems of nerves: (Va), (Vd), (Vc) and (Vd). The first nerve (Va) is slender, branched off from the main nerve (V) at the ventral side of the first internal ventral muscle (234), prolonged antero-laterally and entering the sternal wall at the ventral side of the third internal ventral muscle (236). The second stem (Vb) is thick, branching from the main stem (V) at the side of the first nerve (Va), prolonged backward and entering the first external ventral muscle by subdivision. The third stem (Vc) is long, prolonged latero-posteriorly, giving off two branches—the nerve of the second external ventral muscle (Vc 1) and the nerve of the external tergo-sternal muscles (Vc 2). The fourth stem (Vd) is a distal one of the main nerve (V), prolonged latero-posteriorly and giving off three branches, the nerve of the second external ventral muscle (Vd 1), the nerve of the lateral wall (Vd 2) and the nerve of the external intersegmental tergo-sternal muscles (Vd 3) as in the first abdominal segment.

G. GANGLION AND NERVES OF THE SEVENTH ABDOMINAL SEGMENT

(Fig. 59)

The innervation in the seventh abdominal segment resembles that of the typical abdominal segment, but the second stem of the first nervous root is one-branched, and the nerves corresponding to the first and second stems of the second nervous root in the typical abdomical segment are lacking.

H. GANGLION AND NERVES OF THE EIGHTH AND THE MORE POSTERIOR ABDOMINAL SEGMENTS

(Fig. 59)

The nerves in the eighth and the more posterior abdominal segments branch from four pairs of main nervous roots arising on the eighth or terminal abdominal ganglion.

a. **Terminal Abdominal Ganglion** (Gl)

This ganglion is the last one in the abdomen, situated just upon the anterier end of the common oviduct in the seventh abdominal segment, and it resembles the seventh abdominal ganglion in shape except that it is somewhat larger.

b. **First Root of the Nerves** (I)

This root corresponds to the first root in the typical abdominal segment. It arises on the lateral middle portion of the ganglion, and divides into two main stems (Ia and Ib) at the lateroposterior side of the ganglion. These stems correspond to the first main stem (Ia) and the second main stem (Ib) in the first nervous root of the typical abdominal segment respectively.

The first main stem (Ia) gives off four nerves, (Ia 2), (Ia 3i), (Ia 3ii) and (Ia 5), which correspond to nerves (Ia 2, Ia 3i, Ia 3ii, and Ia 5) in the typical abdominal segment respectively. The first nerve (Ia 2) resembles the nerve (Ia 2) in the typical abdominal segment, but the second (Ia 3i) and third (Ia 3ii) are different from those of the typical abdominal segment in their branching, namely the nerves (Ia 3i and Ia 3ii) directly arise on the main stem (Ia). The third (Ia 5) is two-branched, one is a common branch which gives off the nerve of the eighth abdominal tergal wall, the nerve of the second external dorsal muscle and the nerve of the first external dorsal muscle, and the other is an internal common branch which supplies nerves to the first and the second internal muscle (269, 270).

The second main stem (Ib) of nerves is prolonged backward and divided into several branches which enter the sternal dilators of the vagina (275, 276).

c. Second Root of the Nerves (V)

The second root arises on the posterior side of the first root (I), latero-posteriorly prolonged, and giving off three nerves (Vb, Vd 1 and Vd 2) at the latero-posterior portion of the eighth abdominal segment. The first nerve (Vd) enters the sternal lateral dilators of the vagina (275, 276), the second nerve (Vd 1) supplies the second sternal lateral dilator (276), and the third nerve (Vd 2) is laterally prolonged to enter the lateral wall of the segment.

d. Third Root of the Nerves (I+V)

The third nervous root arises on the latero-posterior portion of the ganglion, prolonged backward, and divided into two stems, the first (I) and the second (V) at the postero-lateral portion of the eighth abdominal segment.

The first stem (I) extends to the dorsal region of the ninth abdominal segment and gives off three main branches, (Ii), (Ia 2) and (Ia5). The first nerve (Ii) is a very slender basal branch of the first stem, and supplied to the antero-lateral tergal wall at the base of the dorsal transverse muscle. The second nerve (Ia 2) is branched from the main stem (Ia) at the lateral portion of the segment, entering the anterior internal tergo-sternal muscles (288-290). The third (Ia 5) is a dorsal nerve of the main stem (Ia) giving off two branches, the nerve of the external dorsal muscle (285) and the nerve of the internal dorsal muscles (283, 284).

The second stem (V) is prolonged backward, giving off three nerves, (Vi), (Vii) and (Viii). The first nerve (Vi) is slender, branched from the basal portion of the main stem (V), and connected with a branch of the second nerve (Ia 2) of the first stem (Ia). The second nerve (Vii) is an anterior branch of the apex of the main stem (V), and enters the retractors of the genital lobe (291, 292) after sub-branching. The third nerve (Viii) is a posterior branch of the apex of the main stem (V), and sub-branched into two, the nerve of the retractors in the genital lobe (291, 292) and the nerve of the wall in the genital lobe (gl).

e. Fourth Root of the Nerves (VI)

This nervous root is also long, arising on the latero-posterior portion of the ganglion at the medio-posterior side of the third root (III), prolonged backward and giving off three main nerves, the nerve of the so-called paraproct (VIa), the nerve of the cercus (VIb) and the nerve of the proctiger (VIc). The nerve of the paraproct (VIa) branches from the main root (VI) at the posterior portion of the ninth abdominal segment, entering the wall of the paraproct (VIa) after sub-branching. The nerve of the cercus (VIb) is short, divided from the main root at the antero-median side of the cercus (cer) and supplying a number of fine sub-branches to the cercal wall. The nerve of the proctiger (VIc) is a terminal stem of the main root, divided into two branches, the nerve (VIc 1) of the anterior lateral wall of the proctiger (prg) and the nerve of the rectal dilators (VIc2).

ii. VISCERAL NERVOUS SYSTEM

1. OESOPHAGEAL SYMPATHETIC NERVOUS SYSTEM

(Fig. 11)

The nervous system is called the supraintestinal sympathetic system or stomatogastric nervous system, and may be divided into two sections, the median and the lateral.

A. MEDIAN SECTION

This group of nerves lies upon the dorsal face of the fore-intestine to which its fibers are mainly supplied. It consists of a median cephalic nerve (C), a frontal ganglion (F), recurrent nerves (R), and is connected with the central nervous system by a pair of arched or frontal ganglion connectives (Fr).

The arched nerve (Fr) arises on the anterior portion of the tritocerebal region, prolonged forward, passing the side of the second dorsal dilator of the pharynx (41) and the retractor of the mouth angle (44); it curves medially then posteriorly around the retractor of the mouth angle, and is connected with the antero-lateral portion of the frontal ganglion (F) at the antero-ventral side of the brain (B).

The frontal ganglion (F) lies upon the median portion of the anterior pharynx at the antero-ventral side of the brain. It is roundish, somewhat flattened, connected with the arched nerve at the antero-lateral portion, and anteriorly giving off a cephalic nerve (frontal nerve by some authors) (C) and posteriorly off a root of recurrent nerves (R).

The cephalic nerve (C) is a median branch arising on the anterior median portion of the frontal ganglion (F), and breaking up into a a pair of branches, each prolonged forward along the median wall of the pharynx and divided into two, one of which is a stem of nerves entering the first and the second dorsal dilator of the buccal cavity (38, 39) and the first dorsal dilator of the pharynx (40) from the median side of these muscles, and the other is a nerve entering the compressor of the labrum (1) after connecting with the labral nerve at the anterior side of the first dorsal dilator of the buccal cavity (38).

The recurrent nerve (R) is median, thick, and arising on the posterior portion of the frontal ganglion, somewhat enlarged at the ventro-posterior side of the brain and fusiform. It breaks up, at the posterior side of the enlarged portion (hypocerebral ganglion by some authors), into a pair of branches which run barckward along the dorsal side of the posterior pharynx and subsequently the dorso-lateral side of the oesophagus and crop. Each of the paired branches of the recurrent nerve is enlarged at the latero-posterior portion of the crop, forming a small ganglion called the stomachic, caudal or ventricular ganglion, which gives off two branches, one of which is a nerve entering the crop by fine sub-branches, the other is a more prolonged backward nerve entering the gastric caecum.

B. LATERAL SECTION

The section consists of a series of two ganglia (Lag 1, Lag 2) on either side of the posterior pharynx. The first ganglion (Lag 1) is an anterior one which is very small, posteriorly connected with the second ganglion (Lag 2) by a nerve (Lagv 2), anteriorly with the postero-median portion of the protocerebral region by a nerve (La) which gives off a branch (Lai) innervating the lateral dilator of the pharynx (47) and the third and fourth dorsal dilators of the pharynx (42, 43). The first ganglion (Lag 1) gives rise to five nerves, the nerves of the pharynx (Lapa, Lapb), the nerve of the trachea (Latr) and the nerve of the second ventral dilator of the pharynx (Lav 2).

The first (Lapa) is a very small nerve which arises on the dorsal portion of the ganglion (Lag 1) and enters the lateral portion of the posterior pharynx after sub-branching. The second nerve (Lapb) is also a small branch which enters the lateral portion of the posterior pharynx and often forms a very small ganglion on the way. The third nerve (Latr) is long and arises on the postero-ventral portion of the ganglion and enters the trachea at the side of the posterior tentorial arm (ptn). The fourth nerve (Lav 2) is a slender branch which arises on the distal portion of the ganglion and is supplied to the second ventral dilator of the pharynx (50).

The second ganglion (Lag 2) of the lateral section is larger than the first ganglion (Lag 1), fusiform, and gives off two main branches, the dorsal and the posterior. The dorsal branch is thick, subdivided into two nerves, one (Lah) of which enters the dorsal vessel, the other (Lacr) is connected with a branch of the recurrent nerve (R) at the posterior pharynx. The posterior branch of the second ganglion (Lag 2) is also divided into two branches, one (Lav 3) of which is slender, entering the third ventral dilator of the pharynx (51), the other (Lao) is thicker and longer than the preceding nerve and supplied to the antero-lateral portion of the oesophagus (oe).

2. VENTRAL SYMPATHETIC NERVOUS SYSTEM

(Figs. 11, 48, 50, 58 and 59)

The ventral sympathetic nervous system consists of unpaired median nerves (Mn) on the ventral nerve cord. The median nerves give off a pair of lateral branches called the transverse nerves (Tn).

The median nerve arising on the suboesophageal ganglion (Sog) is very short, and not connected with the prothoracic ganglion. The transverse nerve (Tn) arising on the median nerve (Mn) is prolonged backward, divided into two branches at the gular region of the head, one of which extends dorso-laterally, enters the anterior lateral wall of the oesophagus (oe), the other extends backwards, enters the prothoracic cavity along the internal tergo-sternal muscles (65, 66) and is connected wlth the nerve (Ia 2) in the prothorax.

Each of the median nerves arising on the thoracic ganglion (G) is similar to that in the suboesophageal ganglion (Sog), but it lacks the branch entering the periphery of the intestine. Its transverse nerve is caudo-laterally extended, passing the under side of the ventral transverse muscle, and connected with a sub-branch of the following ganglion (1a2) at the ventral side of the spiracle of the following segment after supplying a nerve to the ventral transverse muscle.

The median nerve (Mn) arising on the posterior median end in each of the first six abdominal ganglia is long and connected with the anterior median portion of the succeeding ganglion. Its transverse nerve (Tn) arising near the succeeding ganglion is prolonged laterally along the ventral side of the ventral transverse muscle, and connected with a sub-branch of the succeeding ganglion (1a 2) at the lateral intersegmental region. The transverse nerve gives off several branches, the anterior and the posterior nerve, the nerves of the ventral transverse muscle, and the common stem of nerves of the dorsal transverse muscles. The posterior branch (Tnp) arises from the main transverse nerve at the latero-median region of the sternum and connects with the base of the first root (I) of nerves of the followed ganglion. The posterior branch of the transverse nerve on the median nerve between the sixth and the seventh abdominal ganglion is connected with the anterior medio-dorsal portion of the latter ganglion, and its distal portion often unites with that of the same branch in the opposit side. The anterior nerve (Tna) branches from the transverse nerve (Tn) at a position similar to that of the posterior branch (Tnp), is prolonged forward and connected with the posterior branch (Tnp) of the preceded transverse nerve (Tn), but it lacks on the transverse nerve which arises from the median nerve connecting the first abdominal ganglion with the second. The nerves of the ventral transverse muscles are very fine branches which arise from the transverse nerve at a position similar to that of the rising portion of the anterior and the posterior branch and enter the ventral transverse muscle at the medio-lateral region of the sternum. The common stem of the nerves of the dorsal transverse muscles arises from the main transverse nerve at the lateral portion of the intersegmental region, and divides into two branches, the anterior branch entering the posterior dorsal transverse muscle of the preceded segment, and the posterior branch supplied to the anterior dorsal transverse muscle of the segment behind the comman stem.

The median nerve arising on the posterior end of the seventh abdominal ganglion resembles that of the thoracic segment, on the other hand its transverse nerve is similar to that of the typical abdominal segment, but the posterior branch (Tnp) is attached to the anterior medio-dorsal portion of the terminal abdominal ganglion (Gl) after fusing with the same branch on the opposit side.

The posterior side of the terminal abdominal ganglion lacks a median nerve, but has one pair of stems (Tn) which have been included to the ventral sympathetic system.

Each of the stems (Tn) arises on the caudo-lateral portion of the terminal or eighth abdominal ganglion (Gl) in association with the roots of nerves of the ninth and terminal abdominal segments, prolonged dorso-laterally, and divided into three branches, the anterior (Tn 1), the middle (Tn 2) and the posterior branch (Tn 3). The anterior branch (Tn 1) is very long, extending to the fourth abdominal segment and supplied to the anterior portion of the hind intestine at the posterior side of the bases of the Malpighian tubes. The middle branch (Tn2) is prolonged upward and subdivided into two nerves which pass among convolutions of the so-called dorsal sac (dsg) of the ninth abdominal segment and supplied to the middle portion of the hind intestine. The posterior branch (Tn 3) is very long, extending to the proctiger along the ventral side of the hind intestine and innervating the rectum (r).

VI. COMPARISON OF THE MAIN NERVES

In general it has been considered that the brain and the suboesophageal ganglion are formed by fusion of several ganglia of the segments which construct the head respectively. The nerves arising on such specialized portions can not be readily compaired with those of the thorax and the abdomen. The thoracic and the abdominal segments excepting the abdominal terminal ones are, however, distinctly and uniformly divided, and the nervous arrangements are also considerably uniform, therefore the branches of nerves of these segments can be easily compared with one another.

The nerves of the typical abdominal segment arise from two pairs of main roots (I and V), those of the prothorax from three pairs of main roots (I, II and III), and those of the pterothorax from four pairs of main roots (I, II, III and IV).

The first main roots of the nerves (I) of the prothorax and the pterothorax arise on the connectives. These nerves supply the branches to the dorsal and ventral longitudinal muscles and the intersegmental lateral muscles, and have features remarkably similar to those of the branching of the nervous roots (I) in the abdominal segments. The nervous main roots designated as (I) in the prothoracic, the pterothoracic and the abdominal segment may be probably homologous to one another, and those of the thorax may have probably migrated forward far from the ganglia.

The nervous root (II) in the prothorax mainly supplies the branches to the lateral region of the segment at the anterior side of the coxa, this feature also resembles that of the nervous root (II) in the pterothorax. These roots of the nerves may be also homologous to each other.

The nervous root (III) of the prothorax is almost similar to that of the nervous root (III) in the pterothorax, therefore it is undoubted that these are homologous to each other.

The nervous root (IV) is a special nerve in the pterothorax.

It is unknown whether root (V) of the abdominal segment is homologous to either of the nervous roots (II and III) or to both in the thoracic segments. In the present paper the abdominal nervous root (V) is tentatively treated as a nerve different from the thoracic nervous roots (II and III).

The result of comparing the branches of the main nerves in the segments is shown in the following table.

The median unpaired nerve of the ventral nerve cord in the typical abdominal segment is long, connecting with two ganglia and giving off a pair of transverse nerves (Tn) near the succeeding ganglion. Each of the median nerves arising on the suboesophageal ganglion, the thoracic ganglia and the seventh abdominal ganglion, is very short, not connected with the followed ganglion, and divided into two transverse nerves (Tn) at the tip. The terminal abdominal ganglion lacks the median nerve. The type of the median nerves in the typical abdominal segments is very similar to the general type of the median nerves in many larval insects. The type of the median nerves found on the other segments may have been probably modified from the former type.

TABLE I

Comparison of the Main Nerves in the Thoracic and Abdominal Segments

In the table "×" shows the presence of nerves, and "○" shows the absence of the same.

Body segments / Nervous branches.	Prothoracic segment	Mesothoracic segment	Metathoracic segment	1st abdom. segment	2nd–6th abdom. segment	7th abdom. segment	8th abdom. segment	9th abdom. segment
I	×	×	×	○	×	×	×	× I+V)
Ia.	×	×	×	×	×	×	×	×
Ia1.	○	○	○	○	×	×	○	○
Ia2.	×	×	×	×	×	×	×	×
Ia2i.	○	○	○	○	×	×	○	○
Ia2ii.	○	○	○	○	×	×	○	○
Ia3.	○	○	○	○	×	×	○	○
Ia3i.	○	○	○	○	×	×	×	○
Ia3ii.	○	○	○	○	×	×	×	○
Ia4.	○	○	○	○	×	×	○	○
Ia5.	×	×	×	×	×	×	×	×
Ib.	×	×	×	×	×	○	×	○
Ib1.	○	○	○	○	×	○	○	○

Ib2.	○	○	○	○	×	○	○	○
Ib3.	○	○	○	○	×	○	○	○
II.	×	×	×	○	○	○	○	○
IIa.	×	×	×	○	○	○	○	○
IIb.	×	×	×	○	○	○	○	○
IIc.	×	×	×	○	○	○	○	○
IIci.	×	○	○	○	○	○	○	○
IIc2.	×	×	×	○	○	○	○	○
IIc3.	○	×	×	○	○	○	○	○
IIc4.	○	×	×	○	○	○	○	○
IId.	×	×	×	○	○	○	○	○
IId1.	×	○	○	○	○	○	○	○
IId2.	×	○	○	○	○	○	○	○
IId3.	×	○	○	○	○	○	○	○
IId4.	○	×	×	○	○	○	○	○
IId5.	×	×	×	○	○	○	○	○
IId6.	×	○	○	○	○	○	○	○
IId7.	×	×	×	○	○	○	○	○
III.	×	×	×	○	○	○	○	○
IIIa.	×	×	×	○	○	○	○	○
IIIa1.	×	×	×	○	○	○	○	○
IIIa2.	×	×	×	○	○	○	○	○
IIIa2i.	×	×	×	○	○	○	○	○
IIIa2ia.	○	×	×	○	○	○	○	○
IIIa2ıb.	○	×	×	○	○	○	○	○
IIIa2ic.	×	×	×	○	○	○	○	○
IIIa2id.	○	×	×	○	○	○	○	○
IIIa2ii.	×	×	×	○	○	○	○	○
IIIa2iia.	×	×	×	○	○	○	○	○
IIIa2iib.	×	○	○	○	○	○	○	○
IIIa3.	×	×	×	○	○	○	○	○
IIIa^{3}i.	○	×	×	○	○	○	○	○
IIIa3ii.	×	×	×	○	○	○	○	○

Body segments / Nervous branches.	Prothoracic segment	Mesothoracic segment	Metathoracic segment	1st abdom. segment	2nd–6th abdom. segment	7th abdom. segment	8th abdom. segment	9th abdom. segment
IIIa3iia.	○	×	×	○	○	○	○	○
IIIa3iib.	○	×	×	○	○	○	○	○
IIIa3iic.	×	○	○	○	○	○	○	○
IIIa3iii.	×	×	×	○	○	○	○	○
IIIb.	×	×	×	○	○	○	○	○
IIIb1.	×	×	×	○	○	○	○	○
IIIb2.	×	×	×	○	○	○	○	○
IIIb3.	×	×	×	○	○	○	○	○
IIIb4.	×	×	×	○	○	○	○	○
IIIb5.	×	×	×	○	○	○	○	○
IIIb6a.	×	×	×	○	○	○	○	○
IIIb6b.	×	×	×	○	○	○	○	○
IV.	○	×	×	○	○	○	○	○
IVa.	○	×	×	○	○	○	○	○
IVb.	○	×	×	○	○	○	○	○
IVb1.	○	×	×	○	○	○	○	○
IVb2.	○	×	×	○	○	○	○	○
IVb2i.	○	×	×	○	○	○	○	○
IVb2ii.	○	×	×	○	○	○	○	○
IVc.	○	×	×	○	○	○	○	○
IVc1.	○	×	×	○	○	○	○	○
IVc1i.	○	×	×	○	○	○	○	○
IVc1ii.	○	×	×	○	○	○	○	○
IVc2.	○	×	×	○	○	○	○	○
IVc2i.	○	×	×	○	○	○	○	○
IVc2ii.	○	×	×	○	○	○	○	○
IVc2iii.	○	×	×	○	○	○	○	○
IVc2iv.	○	×	×	○	○	○	○	○
IVc2v.	○	×	×	○	○	○	○	○
V.	○	○	○	×	×	×	○	×(I+V)
Va.	○	○	○	○	×	○	○	⊙

Vb.	○	○	○	×	×	○	○	○
Vc.	○	○	○	○	×	×	○	○
Vd.	○	○	○	×	×	×	○	○
Vd1.	○	○	○	×	×	×	×	○
Vd2.	○	○	○	×	×	×	×	○
Vd3.	○	○	○	×	×	×	○	○

VII. SUMMARY

1) This investigation deals anatomically with the skeletons, the muscular system and the female nervous system of *Chauliodes formosanus* PETERSEN.

2) Sexual dimorphism is not conspicuous, but found on the antennae and the ventral regions of the terminal abdominal segments.

3) The hypopharynx is not conspicously projecting, and its dorsal base has a median transverse sclerite and a pair of lateral suspensorial rods. The ventro-posterior ends of the latter rods are fused to the latero-proximal corners of the mentum, and the other ends of the same extend to the dorso-lateral portions of the mouth to form the oral arms.

4) The gulamentum is almost fused to the cranial wall.

5) The spina is situated on the median portion of the sternal intersegmental membrane between the pro- and mesothorax and between the meso- and metathorax, and it projects between the paired connectives of the ventral nerve cord and attaches to the common muscular net of the ventral transverse muscles.

6) The tegula projecting on the anterior basal portion of the wing may be probably a sensory lobe.

7) The furcal arm of the pterothorax has three branches, of which the two anteriors or the first and the second branch are attached to the upper and the lower furca-entopleural muscle respectively, the third is a posterior branch which is the largest of three and fused with the lateral sternal intersegmental apodeme.

8) The pleural suture is internally provided with upper and lower entopleural arms, which are respectively connected with the first and second furcal branches by muscles.

9) The so-called tergal precostae of the typical abdominal segments are very broadly developed.

10) The tenth abdominal tergum is divided into a pair of sclerites, which correspond to the sclerites often called surgonopods in other male insects.

11) The cercus remains in a round elevated plate intercalated between the tenth abdominal tergal sclerite and the so-called paraproct.

12) The so-called paraproct may belong to the tenth abdominal sternum.

13) The external genital organs are very simple in both sexes. The female genitalia consists of a pair of lobes of the ninth abdominal segment. The vagina opens directly on the posterior sternal membranous portion of the eighth abdominal segment. The male genitalia consists of a very short hypandrium and three median tongue lobes, of which two anterior membranous lobes form the anterior and the posterior lip of the genital opening, and the other is a large hard lobe situated on the furthermost posterior side.

14) The so-called dorsal sac of the female genitalia is a very long blind tube (1.5 times as long as the abdomen), which is invaginated on the median membrane between the genital lobes of the ninth abdominal segment, and convolved at the dorsal side of the vagina and the spermatheca.

15) The musculature of the head resembles that of lower Orthopteroid insects.

16) The posterior ends of the abdominal external dorsal muscle are attached on the posterior tergal division very far from the posterior end of the segment.

17) The paratergal muscles are developed on the typical abdominal segments and the prothorax, and those of the abdominal segments consist of several bundles, some of which are intersegmental,

entering the preceding segment and attached on the antero-lateral portions of the posterior tergal plate of the preceding segment.

18) Each abdominal segment from the second to the seventh has two pairs of dorsal transverse muscles, anterior and posterior. Each of the first, the eighth and the ninth abdominal segment has only the anterior pair.

19) Each of the meso- and the metathoracic segment and the second to the seventh abdominal segment has two pairs of ventral transverse muscles, anterior and posterior. Each of the prothoracic and the first abdominal segment is provided with only the posterior pair, and the eighth abdominal segment with only the anterior pair. These muscles are connected with one another and form a common ventral muscular net: The latter net is attached to the apexes of the spinae arising on the intersegmental membranes of the thorax between the thoracic paired connectives of the ventral nerve cord at the sternal median line.

20) The prothoracic nerves branch from three pairs of main roots arising on the connectives and the ganglion; the pterothoracic nerves from four pairs of nervous roots arising on the connectives and the ganglion; and the nerves of the typical abdominal segment from two pairs of nervous roots arising on the ganglion. The first nervous roots of these segments are homologous to one another, though the roots of the thoracic segments arise on the connectives. The second and third nervous roots of the prothorax are homologous to those of the pterothoracic segment respectively.

21) The median nerves arising on the posterior portions of the abdominal ganglia except the terminal ganglion in the ventral nerve cord are connected with the anterior portions of the succeeding ganglia one after another, but those arising on the suboesophageal ganglion and the thoracic ganglia are very short and not connected with the succeeding ganglia.

22) The transverse nerves of the typical abdominal segment are uniform, arising on the median nerves near the succeeding ganglion, connected with the sub-branches of nerves of the succeeding ganglion

at the intersegmental region, and giving off posterior and anterior branches, the former branches are connected with the basal portions of the first nervous stems of the succeeding ganglion, and the latter branches have connections with the posterior branches of the preceding transverse nerves, furthermore the transverse nerves supply branches to the dorsal and ventral transverse muscles. On the transverse nerves in the other segments various modifications are found.

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IX. ABBREVIATIONS

A. Skeletal Structure

a	Antenna.
ac	Antacoila.
acs	Sternal antecosta.
act	Tergal antecosta.
acx	Precoxale.
aes	Anepisternum.
amv	Anterior median ventral sclerite of neck.
an	Anus.
anw	Anterior notal wing process.
ap	Apodemes.
apl	Abdominal pleuron.
apv	Anterior paired ventral sclerite of neck.
ar	Antartis.
as	Abdominal sternum.
asc	Antennal sclerite.
asu	Antennal suture.
at	Abdominal tergum.
atn	Anterior tentorial arm.
atp	Anterior tentorial pit.
aux	Auxilia.
axl	First axillary.
ax2d	Dorsal plate of second axillary.
ax2v	Ventral plate of second axillary.
ax3d	Dorsal plate of third axillary.
ax3v	Ventral plate of third axillary.
ax4	Fourth axillary.
b	Basalar sclerite.
bc	Basicoxite.
bcs	Basicostal suture.
bs	Basisternum.
c	Coxa.
ca	Cardo.
cb	Closing rod of spiracle.
cc	Coxacoila or pleural coxal process.
ce	Compound eyes.
cer	Cercus.
cl	Clypeus.
cr	Coxartis.
cs	Coronal suture.
csd	Common salivary duct.
cw	Claw.
dsg	Dorsal sac of female genitalia.
dsp	Duct of spermatheca.
dtn	Dorsal tentorial arm.

ej	Ejaculatory duct.
em	Epimeron.
epp	Epipharynx.
eps	Epistomal suture.
es	Episternum.
f	Femur.
fc	Femacoila.
fl	Flagellum.
fr	Femartis.
fao	Frontal region.
fu	Furca.
fua	Furcal arm.
fua1–fua3	Sub-branches of furcal arm.
fup	Furcal pit.
fus	Furcasternum.
g	Gena.
ga	Galea.
gf	Genital aperture of female.
gl	Genital lobe of female.
gm	Genital aperture of male.
gum	Gulamentum.
h	Hypandrium.
hg	Hypogonium.
hp	Hypopharynx
ht	Heart.
i	Incisor.
is	Intralar sclerite.
kes	Katepisternum.
lc	Lacinia.
lg	Ligula.
li	Labium.
lo	Lateral ocelli.
lp	Labial palpi.
lr	Labrum.
ls	Labral suture (clypeo-labral suture).
lsiap	Lateral sternal intersegmental apodeme.
ltiap	Lateral tergal intersegmental apodeme.
m	Meron.
md	Mandible.
mdpc	Postcoila of mandible.
mdpr	Postartis of mandible.
mlg1–mlg3	Median lobes of male genitalia.
mn	Mentum.
mo	Median ocellus.
mol	Molar.
mpd1–mpd2	Median plates of dorsal wing base.
mpv	Median plates of ventral wing base.
mx	Maxilla.
mxp	Maxillary palpus.
oa	Oral arm of suspensorial rod of hypopharynx.
oe	Occipital region.

oe	Oesophagus.
os	Ocular sclerite.
osu	Ocular suture.
ov	Oviduct.
pa	Parietal region.
pac	Paracoila.
pami-pamii	Pleural arm (entopleuron).
par	Parartis.
pc	Tergal precosta and pterothoracic postscutellum.
pcb	Postcoxal bridge.
pcs	Sternal precosta.
pcmd	Precoila of mandible.
pd	Pedicel.
pg	Postgena.
ph	Phragma.
plw	Pleural wing process.
pmn	Prementum.
pnas	Posterior plate of ninth abdominal sternum.
pnw	Posterior notal wing process.
poc	Postocciput.
pol	Postlabia.
posu	Postoccipital suture.
pp	Paraproct.
ppai-ppaii	Pits of pleural arms.
pral	Lateral prealar sclerite.
pram	Median prealar sclerite.
prg	Proctiger.
prl	Prelabia.
prmd	Preartis of mandible.
psu	Pleural suture.
pt	Protergum.
pta	Pretarsus.
ptl	Patella.
ptn	Posterior tentorial arm.
ptp	Posterior tentorial pit.
r	Rectum.
s	Scape.
sa	Subalare.
sc	Sternacoila.
scl	Scutellum.
scr	Scutal ridge.
scu	Scutum.
si	Spina.
snw	Second anterior notal wing process.
sp	Spiracle.
spe	Spermatheca.
spu	Spur.
sr	Sternartis.
ssu	Scutal suture.
st	Stipes.
su	Suralar sclerite.

ta1–ta5	Tarsal segment.
tapd	Pit of depressor apodeme of tarsus.
tbh	Transverse bar of hypopharynx.
tc	Tibiacoila.
tg	Tegula.
th	Tendinous thickening of femoro-tibiai articular membrane.
ti	Tibia.
tic	Tibiacaput.
tipd	Pit of tibial depressor.
tipl	Pit of tibial levator.
tn	Trochantin.
tnb	Tentorial dody.
to	Torma.
tpd	Pit of depressor apodeme of trochanter.
tpl	Pit of levator apodeme of trochanter.
tr	Tibiartis.
trc	Trochanter.
trcc	Trochacoila.
trcr	Trochartis.
troc	Trochocaput
tsp	Tibial spur.
tu	Tubercula.
u1–u2	Unguitractor plates.
v	Vagina.
vl	Ventro-lateral sclerites of neck.
w	Wing.
1a–10a	Abdominal segments.
1t	Prothorax.
2t	Mesothorax.
3t	Metathorax.

B. Muscular System

The Muscles are shown by numerical designations as follows: 1–307. The names of muscles are omited here. Therefore readers must look for the names in the chapter on muscular system by their designations.

C. Nervous System

Ai	First antennal nerve.
Aii	Second antennal nerve.
Ad	Nerve of antennal depressor.
Af	Nerve of flagellar muscles.
Al	Nerve of antennal levator.
Ar	Antennal nervous root.
B	Brain.
C	Cephalic nerve (frontal nerve by some authors).
F	Frontal ganglion.
Fr	Frontal ganglion connective (arched or frontal nerve).
G	Thoracic and abdominal ganglia of ventral derve cord.
Gl	Eighth or terminal abdominal ganglion.

H	Hypocerebral ganglion.
L	Root of labral nerves.
L1	Nerve of labral wall.
L2	Stem of nerves of anterior and posterior retractors of labrum.
La	Lateral paired nerve connecting lateral sectors of visceral nervous system with brain.
Lai	Nerves of dorsal and lateral posterior pharyngeal dilators.
Lacr	Nerve connecting recurrent nerve with second ganglion in lateral section of oesophageal sympathetic syetem.
Lag1	First ganglion in lateral section of oesophageal sympathetic system.
Lag2	Second ganglion in lateral section of oesophageal sympathetic system.
Lagr2	Connecting nerve of first and second ganglions in lateral section of oesophageal sympathetic system.
Lah	Nerve of dorsal blood vessel.
Lao	Nerve of oesophagus.
Lapa	Nerves of posterior pharyngeal compressors.
Lapb	Neaves of posterior pharyngeal compressors.
Latr	Nerve of trachea.
Lav2	Nerve of second ventral pharyngeal dilator.
Lav3	Nerve of third ventral pharyngeal dilator.
Lb	Root of anterior labial nerves.
Lba	First main branch of anterior labial nerves.
Lba1	Nerve of median retractor of mentum.
Lba2	Nerve of median retractor of prementum.
Lbb	Second main branch of anterior labial nerves.
Lbb1	Nerve of lateral retractor of prementum.
Lbb2	Nerve of labial palpus.
Lbb3	Stem of nerves entering ventral dilators of common salivary duct and extensor of labial palpus.
Lbb4	Nerve of wall of ligula.
Lo	Lateral ocellar pedicel.
M	Root of mandibular nerves.
M1	Nerve of tergal adductor of mandible.
M2	Nerve of tergal abductor of mandible.
M3	Stem of nerves of sternal adductor and wall in mandible.
M4	Nerve of clypeal wall.
Ma	Root of maxillary nerves.
Mai-Maiii	First, second and third main stems of maxillary nerves.
Mai1	Stem of nerves of adductors of cardo and stipes.
Mai1c	Nerve of adductors of cardo.
Mai1s	Nerve of adductors of stipes.
Mai2	Stem of nerves of promotor of cardo, levator of maxillary palpus, and cranial flexor of stipes.
Mai2c	Nerve of promotor of cardo.
Mai2p	Nerve of levator of maxillary palpus.
Mai2s	Nerve of cranial flexor of stipes.
Maiig	Nerve of flexor of galea.
Maiil	Nerve of stipital flexor of lacinia.
Maiipd	Nerve of depressor of maxillary pulpus.
Maiipl	Nerve of levator of maxillary pulpus.
Maiiig	Nerve of galeal wall.

Maiiil	Nerve of lacinial wall.
Maiiip	Nerve of maxillary palpus.
Mas	Nerve of adductor of stipes.
Mn	Median nerves.
Mo	Median ocellar pedicel.
Pc	Paraoesophageal connecfives or crura cerebri.
Poc	Postoesophageal commissure.
Pvl	Nerve of first ventral pharyngeal dilator.
R	Recurrent nerve.
Rb	Paired branches of recurrent nerve.
So	Posterior labial nerve.
Sol	Nerve of retractor of hypopharynx.
So2	Nerve of postoccipital wall.
So3	Nerve of salivary gland.
Sog	Suboesophageal ganglion.
Tn	Transverse nerve.
Tnl–Tn3	Branches of eighth abdominal transverse nerve.
Tna	Anterior branch of transverse nerve.
Tnp	Posterior branch of transverse nerve.
I	Root of nerves of dorsal and ventral muscles, some lateral muscles, and body wall.
Ia	Main stem of nerves of dorsal and lateral muscles, and body walls.
Ial	Nerve of sternal wall.
Ia2	Stem of nerves of lateral muscles and wall.
Ia2i	Stem of nevers of lateral muscles and muscles of spiracle.
Ia2ii	Nerves of lateral wall.
Ia3	Stem of nerves of tergeal and lateral walls.
Ia3i	Nerve of posterior tergal wall of preceding segment.
Ia3ii	Nerve of pleural wall.
Ia4	Nerve of antero-lateral tergal wall.
Ia5	Stem of nerves of dorsal muscles and dorsal transverse muscles.
Ib	Main stem of nerves of ventral muscles.
Ibl	Nerve of first internal ventral muscle.
Ib2	Stem of nerves of second and third internal ventral muscles and second external ventral muscles.
Ib3	Nerve of third internal ventral muscle.
Ii	Nerve of ninth abdominal tergal wall of terminal abdominal ganglion.
II	Root of nerves of lateral and anterior coxal muscles and body wall.
IIa	Nerve of anterior sternal wall.
IIb	Main stem of nerves of lateral and anterior coxal muscles, trachea and body wall.
IIba	Stem of nerves of lateral and coxal muscles and sternal wall in prothorax.
IIbal	Nerve of anterior coxal muscle of sternum.
IIba2	Nerve of third external intersegmental tergo-sternal muscle.
IIba3	Stem of nerves of second, third and fourth external tergo-sternal muscles and first tergo-pleural muscle.
IIba4	Nerve of sternal wall and anterior intersegmental tergo-furcal muscle.
IIba5	Nerve of pleural abductor of coxa.
IIbb	Stem of nerves of some tergo-sternal muscles, tergal promotors of coxa and tergal wall in prothorax.

IIbb1	Stem of nerves of first external intersegmental tergo-sternal muscle and second and third internal tergo-sternal muscles.
IIbb2	Nerve of tergal wall.
IIbb3	Nerve of tergal wall.
IIbb4	Nerve of posterior tergal wall.
IIbb5	Nerve of first and second tergal promotors of coxa.
IIb1	Nerve of pleural wall.
IIb2	Main stem of nerves of lateral and anterior coxal muscles and trachea in pterothorax.
IIb2i	Nerve of first tergo-sternal muscle.
IIb2ii	Stem of nerves of tergal promotor of coxa, tergo-sternal muscles and trachea.
IIb2iia	Nerve of tergal promoter of coxa.
IIb2iib	Tracheal nerve.
IIb2iic	Stem of nerves of second and third tergo-sternal muscles.
IIb2iic1	Nerve of second tergo-sternal muscle.
IIb2iic2	Connector of IIb2iic and IIb2iii.
IIb2iii	Stem of nerves of first, second and third tergo-pleural muscles.
IIb3	Main stem of nerves of lateral and coxal muscles and muscles of wing in pterothorax.
IIb3i	Stem of nerves of pleural abductor and pronator-extensors of wing.
IIb3ia	Nerve of pleural promotor of coxa.
IIb3ib	Nerve of pleural abductor of coxa.
IIb3ic	Nerve of sternal pronator extensor of wing.
IIb3ii	Connector of IIb3 and IIb2iib.
IIb3iii	Nerve of fourth tergo-pleural muscle.
IIb3iv	Connector of IIb and IIb2iii.
IIb3v	Connector of IIb3 and IIIa2id.
IIc	Stem of nerves of sternal promotor and thoracic trochanteral depressors.
IIc1	Nerve of anterior sternal promoter of coxa.
IIc2	Nerve of furcal depressor of trochanter.
IIc3	Nerve of pleural depressor of trochanter.
IIc4	Nerve of tergal depressor of trochanter.
IId	Stem of nerves of pleural abductor of coxa, levators of trochanter, reductor of femur, and walls.
IId1	Nerve of sternal wall.
IId2	Nerve of pleural wall.
IId3	Nerve of pleural abductor of coxa.
IId4	Nerve of coxal wall.
IId5	Nerve of first levator of trochanter.
IId6	Nerve of levator apodeme of trochanter.
IId7	Connecting branch of nerve (IId) and nerve (IIIb).
III	Root of nerves of lateral muscles, leg muscles and body wall.
IIIa	Stem of nerves of lateral, coxal and trochanteral muscles, and body wall.
IIIa1	Nerves of posterior sternal remoter.
IIIa2	Stem of nerves of lateral and coxal muscles.
IIIa2i	Common nerve of lateral muscles, muscles of wing and trachea.
IIIa2ia	Nerve of coxal depressor-extensor of wing.
IIIa2ib	Tracheal nerve.

IIIa2ic	Nerve of tergo-pleural muscle.
IIIa2id	Nerve of pleuro-axillary muscle.
IIIa2iia1	Nerve of first tergal remotor of coxa.
IIIa2iia2	Nerve of second tergal remotor of coxa.
IIIa2iia3	Nerve of third tergal remotor of coxa.
IIIa2iib	Nerve of latero-posterior wall of protergal plate.
IIIa3	Main stem of posterior coxal nerves.
IIIa3i	Nerve of furca-entopleural muscles.
IIIa3iia	Stem of nerves of pleural remotor of prothorax and coxal deptessor-extensor of wing of pterothorax.
IIIa3iib	Nerve of first tergal remoter of coxa.
IIIa3iic	Pleural remotor of coxa of prothorax.
IIIa3iii	Stem of nerves of levators of trochanter.
IIIa3iiia	Nerve of second levator of trochanter.
IIIa3iiib	Nerve of third and fourth levator of trochanter of prothorax, nerve of third levator of trochanter of pterothorax.
IIIb	Main stem of leg nerves.
IIIb1	Nerve of anterior sternal promotor.
IIIb2	Nerve of coxal wall.
IIIb3i	Nerve of first coxal depressor of trochanter.
IIIb3ii	Nerve of second coxal depressor of trochanter.
IIIb3iii	Nerve of third coxal depressor of trochanter.
IIIb4	Stem of nerves of reductor of femur and trochanteral wall.
IIIb5	Nerve of tibial levator.
IIIb6a	Stem ot nerves of tibial depressor and tarsal muscles.
IIIb6b	Stem of nerves of tarsal muscles.
IV	Stem of nerves of wing and walls.
IVa	Nerve of pleural wall.
IVb	Stem of herves of costal and subcostal veins and tegula.
IVb1	Nerve of tegula.
IVb2i	Nerve of costal vein.
IVb2ii	Nerve of subcostal vein
IVc1	Stem of nerves of radial and median veins.
IVc1i	Nerve of radial vein.
IVc1ii	Nerve of median vein.
IVc2	Stem of nerves of cubital and anal veins.
IVc2i	Nerve of cubital vein.
IVc2ii–IVc2v	Nerves of anal veins.
V	Root of nerves of ventral longitudinal muscles, external intersegmental muscles and body walls.
Va	Nerve of antero-lateral sternal wall.
Vb	Nerve of first external ventral muscle.
Vc	Stem of nerves of external ventral muscle and external tergo-sternal muscles.
Vc1	Nerve of second external ventral muscle.
Vc2	Nerve of external tergo-sternal muscles.
Vd	Stem of nerves of second external ventral muscle, external inter segmental tergo-sternal muscle and body wall.
Vd1	Nerve of second external ventral muscle.
Vd2	Nerve of body wall.
Vd3	Nerve of external intersegmental tergo-sternal muscles.

Vi	Connecting nerve of Ia2 and V in ninth abdominal segment.
Vii	Nerve of retractors of female genital lobe.
Viii	Stem of nerves of retractors and wall in female genital lobe.
VI	Root of nerves of terminal abdominal segments.
VIa	Nerve of paraproct.
VIb	Nerve of cercus.
VIc	Nerve of proctiger.
VIc1	Nerve of wall of proctiger.
VIc2	Nerve of rectal muscles.

X. EXPLANATION OF THE PLATES

Plate I

Fig. 1. Head, side view.

Fig. 2. Head, postero-ventral espect.

Fig. 3. Head, antero-dorsal aspect.

Fig. 4. Anterior portion of cranium, inner side, showing labral muscles and some muscles of stomodaeum.

Fig. 5. Antennal nerves and flagellar muscles of female, dorsal aspect.

Fig. 6. Antennal nerves and flagellar muscles of male, dorsal aspect.

Fig. 7. Innervation of basal portion in right fore leg, posterior aspect.

Fig. 8. Innervation of basal portion in right middle leg, posterior aspect.

Plate II

Fig. 9. Right half of head, inner side, showing antennal, mandibular, maxillary and stomodaeal muscles, and nerves of mandible, maxilla and antenna.

Fig. 10. Right half of head, inner side, showing mandibular and maxillary muscles and nerves.

Fig. 11. Right half of head, inner side, showing stomodaeal labial and labral muscles and nerves.

Fig. 12. Labial musculature, antero-dorsal aspect.

Fig. 13. Hypopharynx and labium, latero-anterior aspect.

Plate III

Fig. 14. Thorax, lateral aspect.

Fig. 15. Thorax, ventral aspect.

Fig. 16. Thorax, dorsal aspect.

Fig. 17. Latero-ventral region of metathorax and first abdominal segment, inner side.

Fig. 18. Innevation of left wings, ventral aspect.

Plate IV

Fig. 19. Anterior portion of abdomen, lateral aspect.

Fig. 20. Posterior portion of female abdomen, lateral aspect.

Fig. 21. Posterior portion of female abdomen, ventral aspect.

Fig. 22. Posterior portion of female abdomen, dorsal aspect.

Fig. 23. Posterior portion of male abdomen, ventral aspect.

Fig. 24. Posterior portion of male abdomen, lateral aspect.

Fig. 25. Posterior portion of male abdomen, dorsal aspect.

Fig. 26. Male terminal abdominal portion, ventral aspect, showing posterior side of third genital lobe, sternal region and anus.

Fig. 27. Male terminal abdominal portion, ventral aspect, showing genital opening and three genital lobes.

Fig. 28. Right half of posterior portion of male abdomen, inner side, showing musculature.

Plate V

Fig. 29. Muscles and nerves of right hind leg, posterior aspect.

Fig. 30. Musculature of right middle leg, posterior aspect.
Fig. 31. Musculature of right fore leg, posterior aspect.
Fig. 32. Left fore leg, anterior aspect.
Fig. 33. Coxo-trochanteral articulation, medio-ventral aspect.
Fig. 34. Coxo-trochanteral articulation, lateral aspect.
Fig. 35. Trochantero-femoral articulation, dorsal aspect.
Fig. 36. Femoro-tibial articulation, lateral aspect.
Fig. 37. Femoro-tibial articulation, ventral aspect.
Fig. 38. Tibio-tarsal articulation, ventral aspect.
Fig. 39. Tibio-tarsal articulation, dorso-lateral aspect.
Fig. 40. Articulation of first and second tarsal segments, ventral aspect.
Fig. 41. Articulation of first and second tarsal segments, dorsal aspect.
Fig. 42. Distal portion of tarsus, ventral aspect.
Fig. 43. Distal portion of tarsus, dorsal aspect.
Fig. 44. Muscles of coxa and trochanter of right fore leg, posterior aspect.
Fig. 45. Base of right middle leg, proximal aspect, showing attachment of coxal and trochanteral muscles.

Plate VI

Fig. 46. Female left antenna, dorsal aspect.
Fig. 47. Musculature and innervation of maxilla, antero-dorsal aspect.
Fig. 48. Right half of prothorax, inner side, showing musculature and innervation.
Fig. 49. Right half of prothorax, inner side, showing musculature.

Plate VII

Fig. 50. Right half of pterothorax and first abdominal segment, inner side. showing musculature and innervation.

Plate VIII

Fig. 51. Right half of pterothorax and first abdominal segment, inner side, showing musculature removed some inner muscles.
Fig. 52. Right half of pterothorax and first abdominal segment, inner side, showing some nerves, and musculature removed some muscles.
Fig. 53, Antennal basal segments, median aspect.
Fig. 54. Antennal basal segments, lateral aspect.

Plate IX

Fig. 55. Male left antenna, dorsal aspect.
Fig. 56. Right half of pterothorax, inner side, showing some nerves and muscles.
Fig. 57. Right half of pterothorax, inner side, showing muscles situated on lateral side.

Plate X

Fig. 58. Musculature and innervation of right half of typical abdominal segment, inner side.
Fig. 59. Right half of posterior portion of female abdomen, inner side, showing musculature and innervation.

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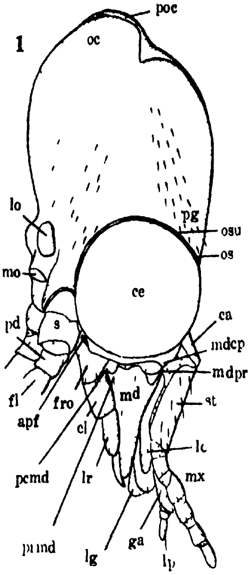
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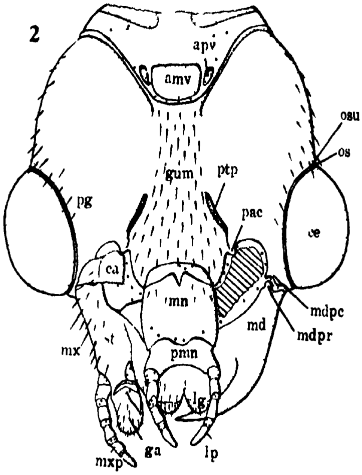
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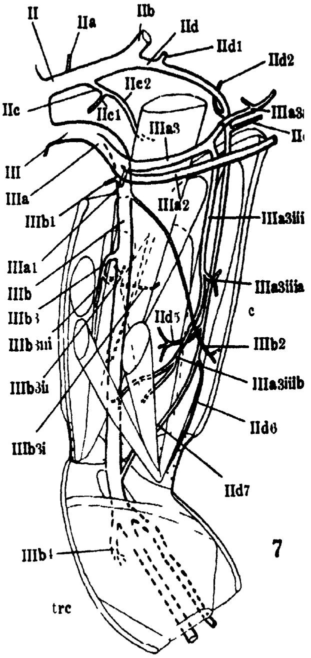
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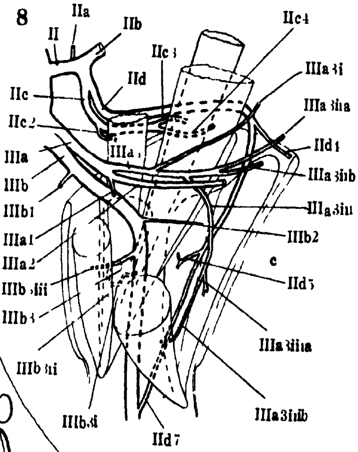
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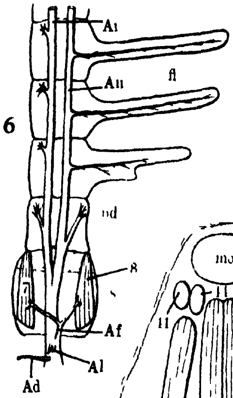
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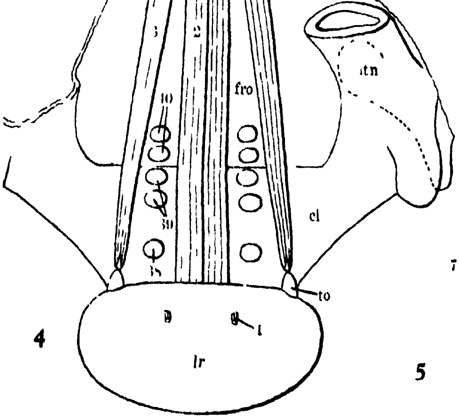
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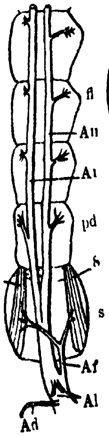
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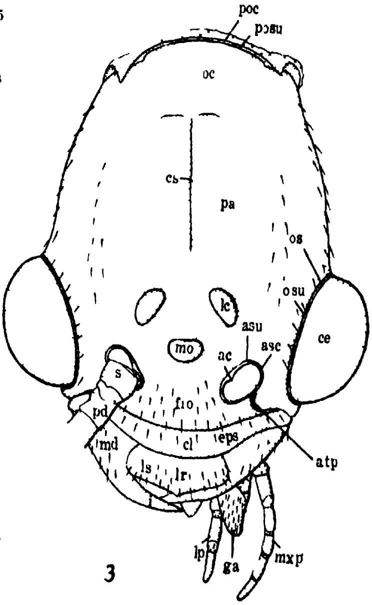
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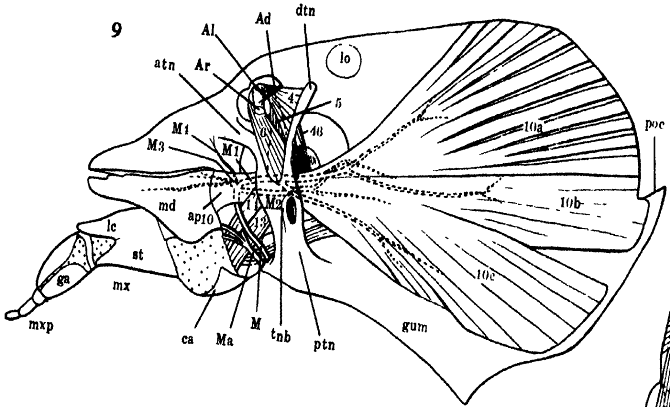
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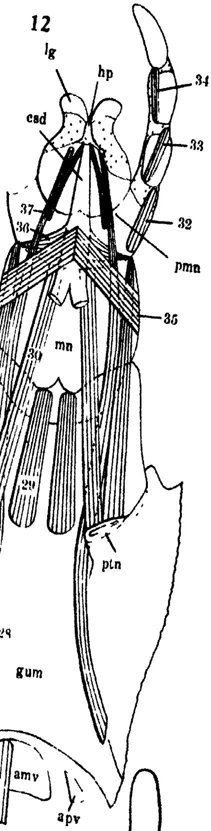
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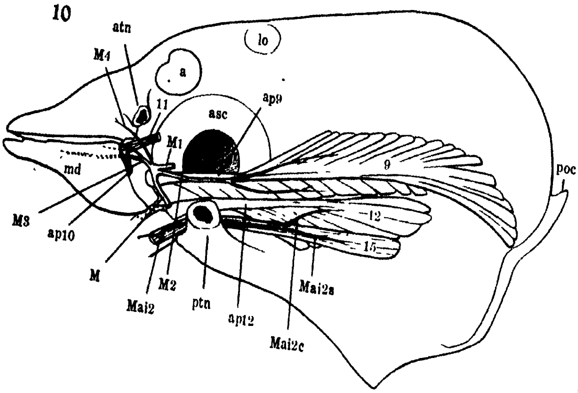
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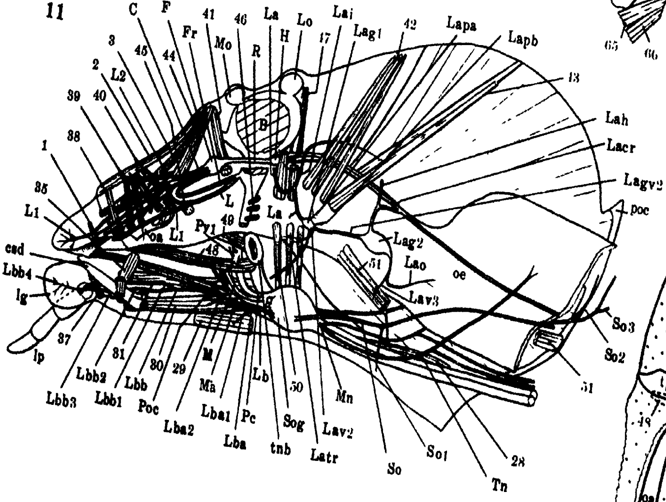
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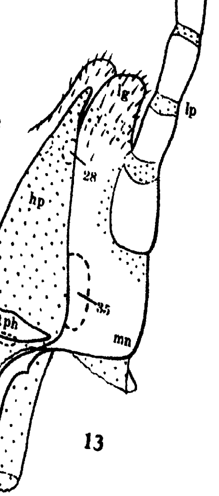
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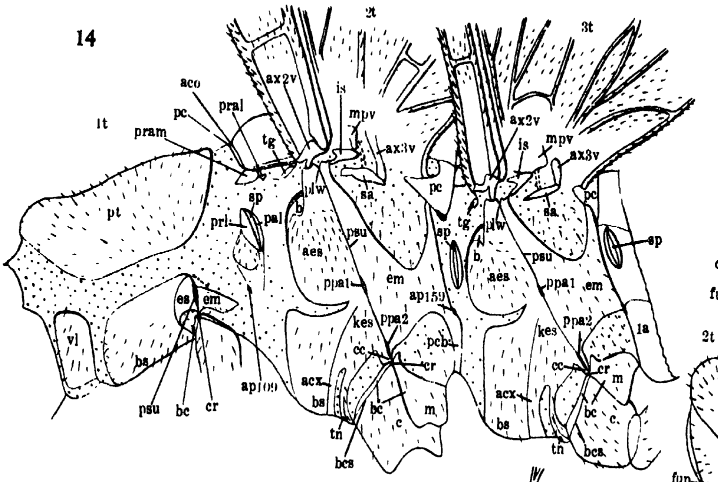
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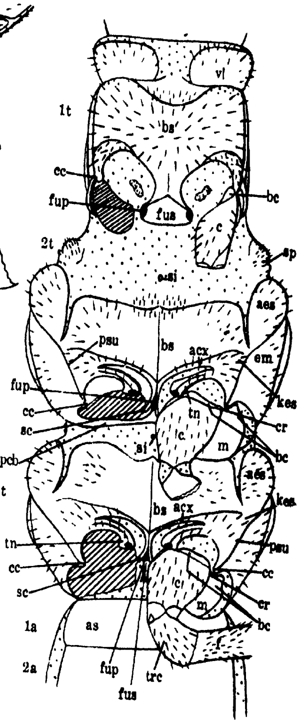
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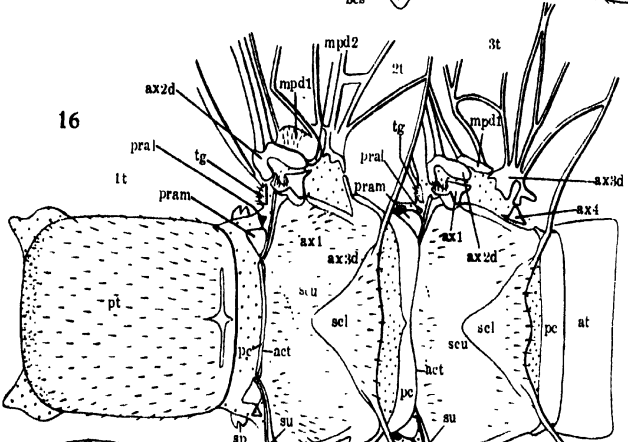
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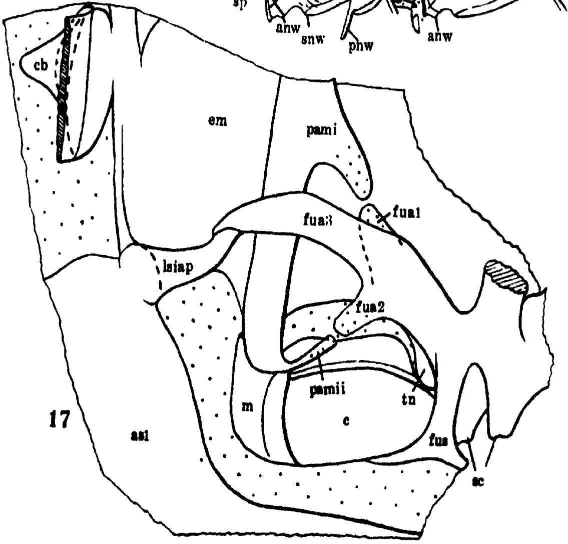
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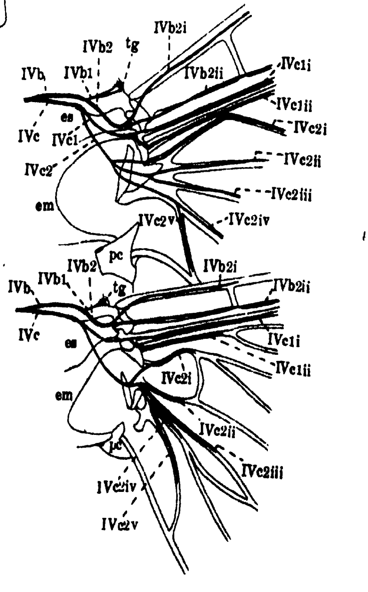
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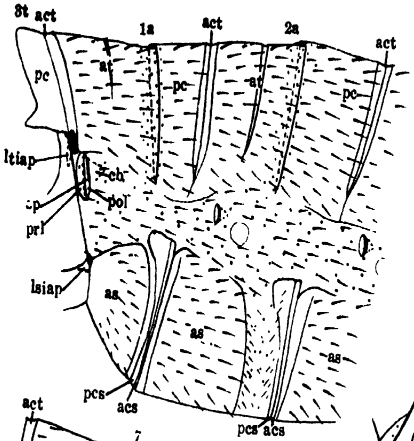

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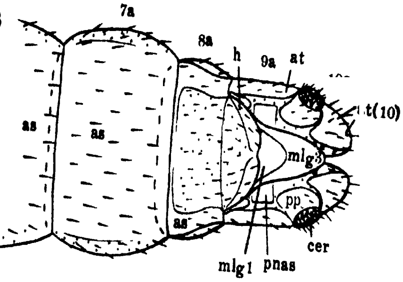

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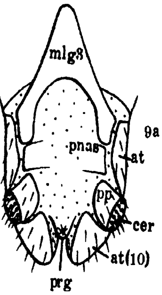

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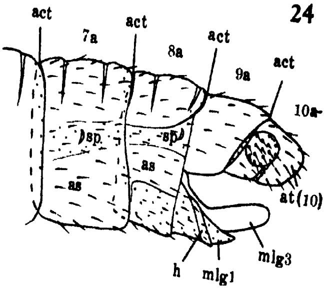

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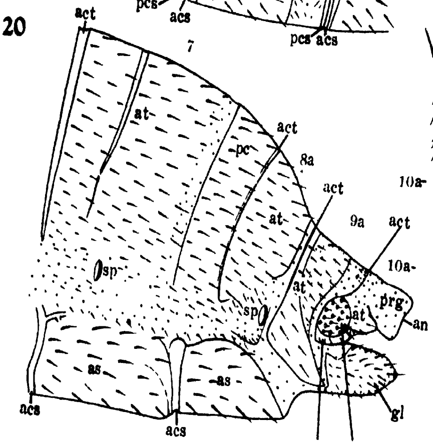

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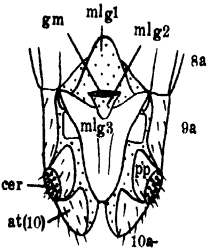

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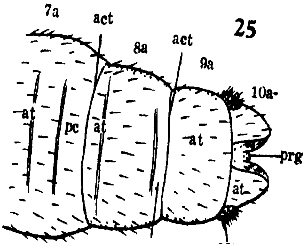

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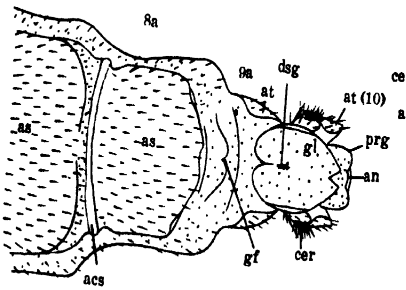

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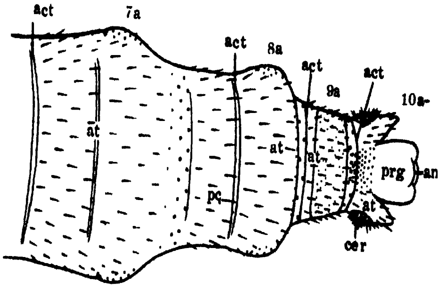

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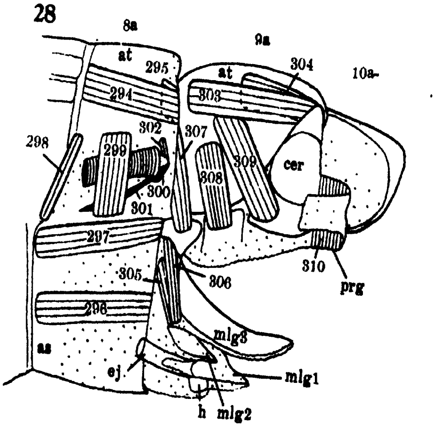

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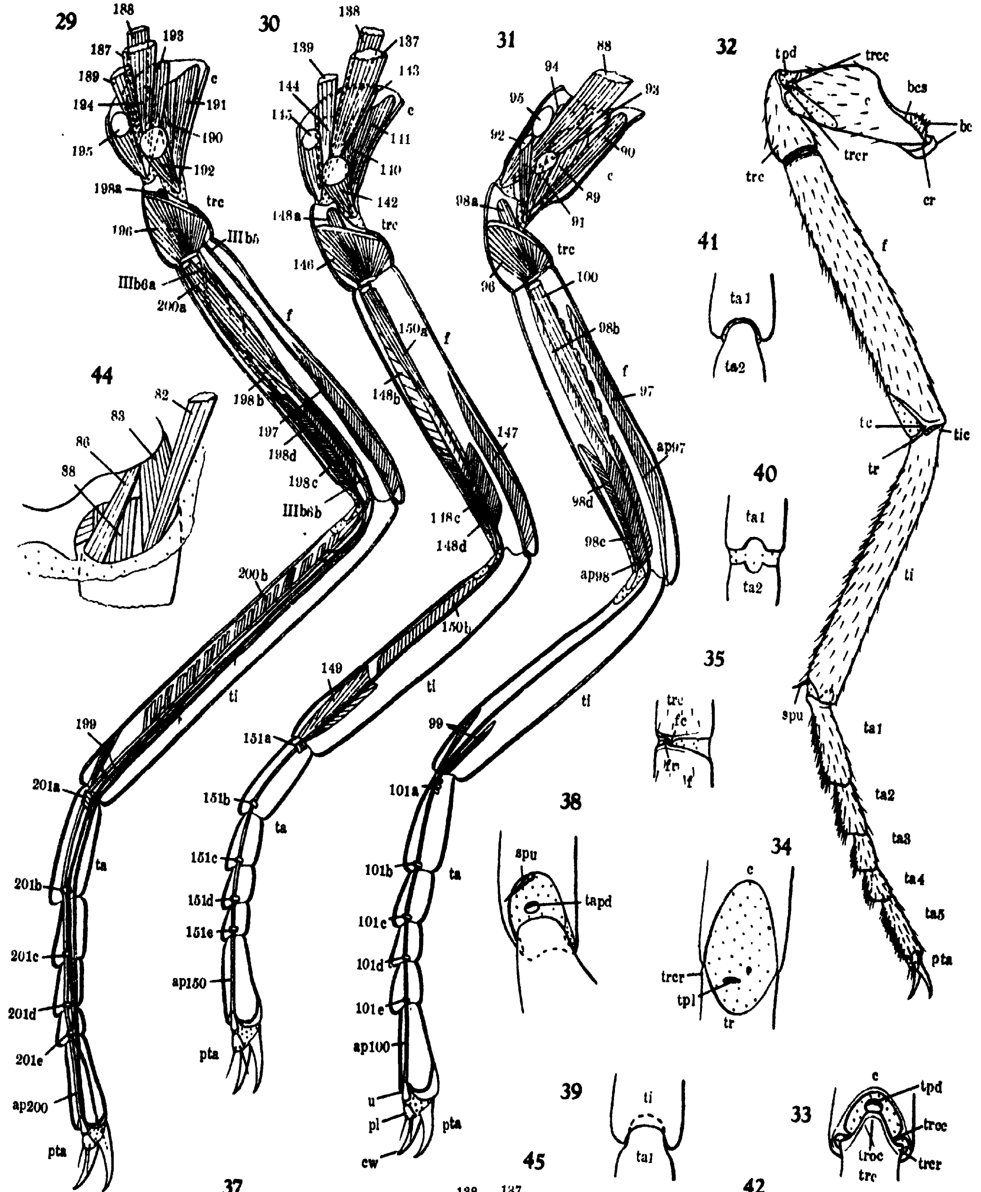

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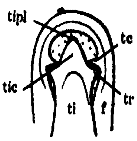

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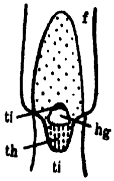

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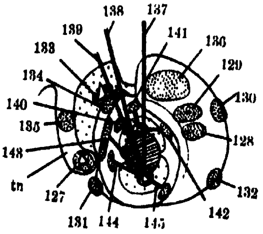

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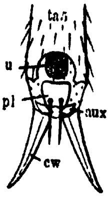

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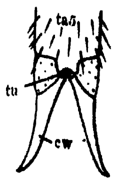

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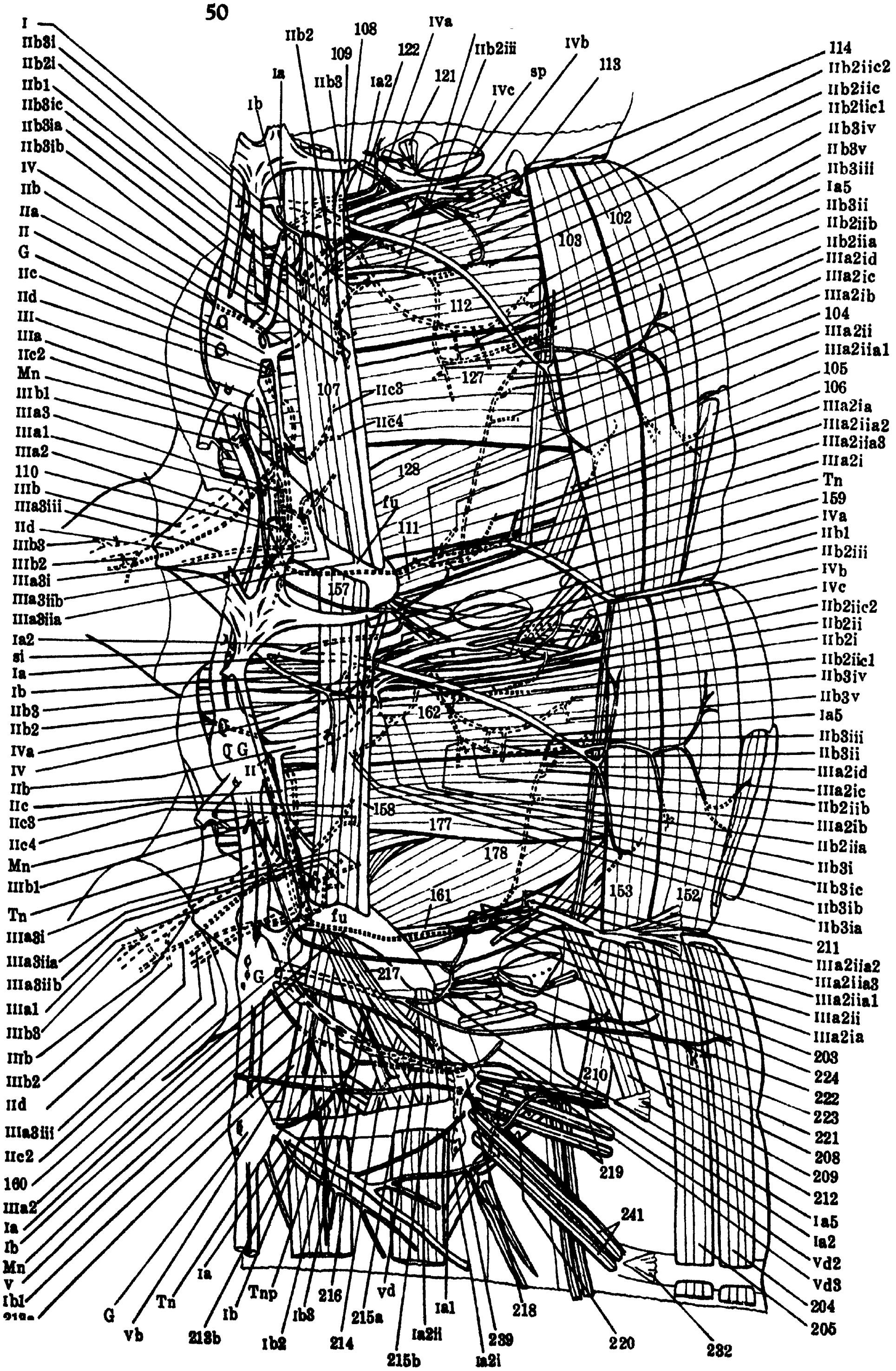
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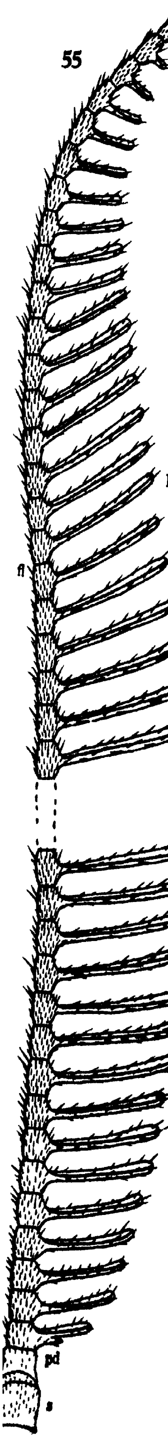
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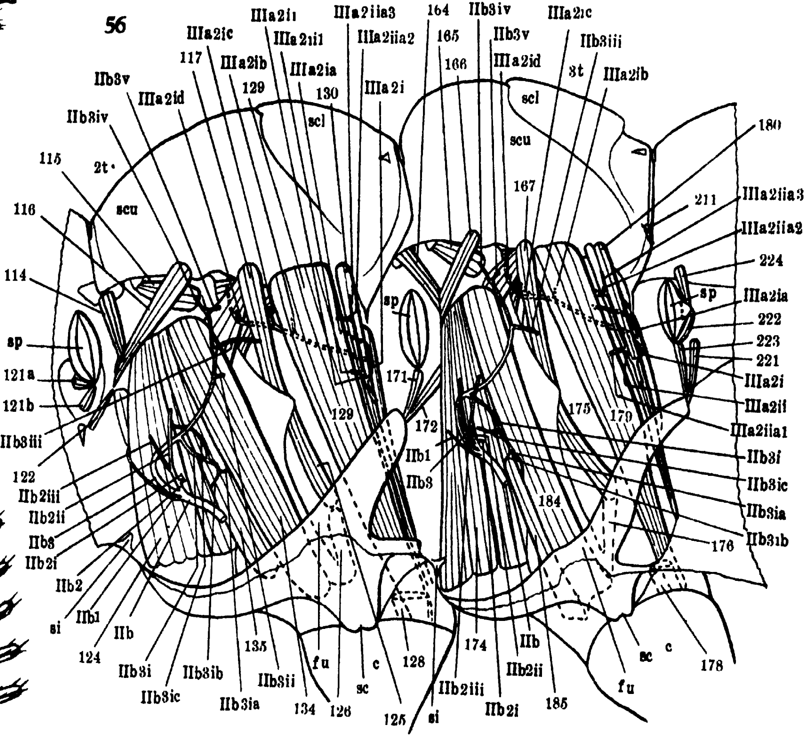
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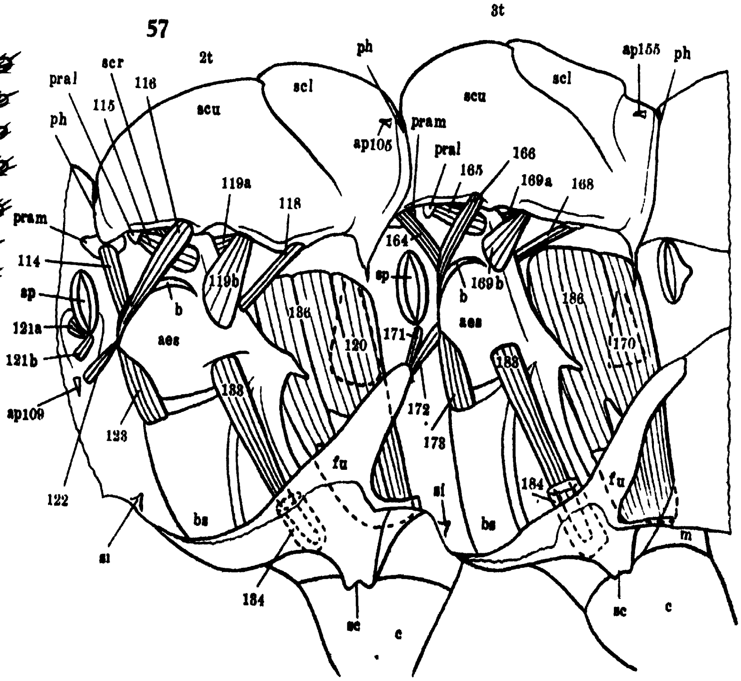
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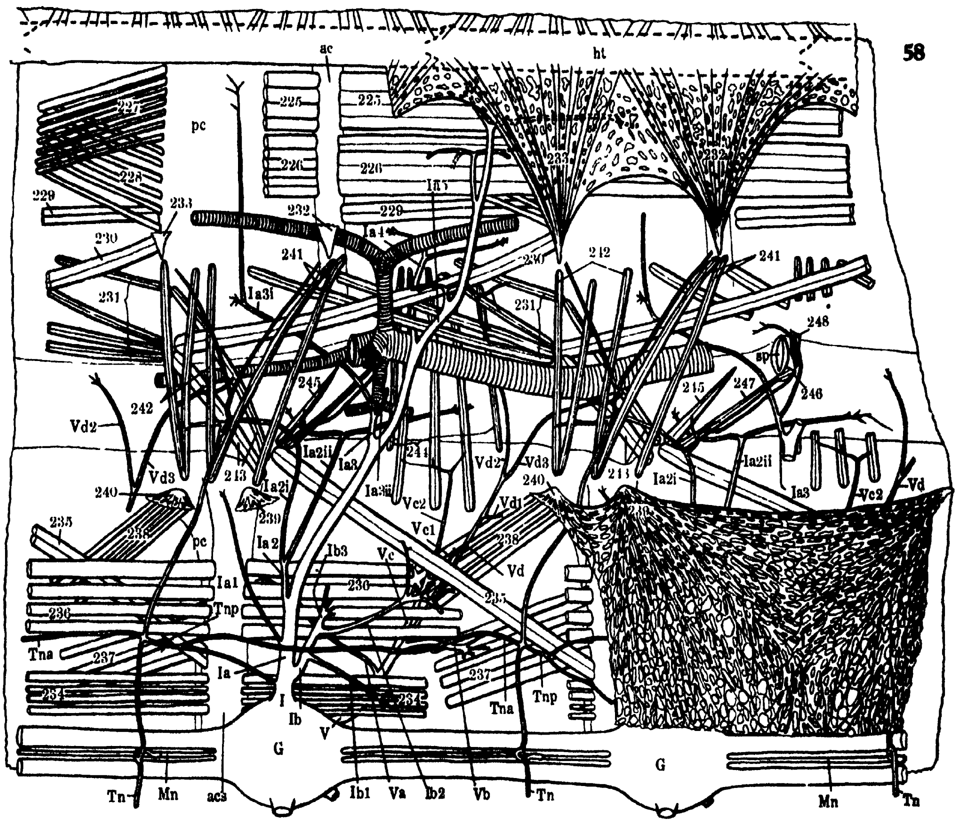
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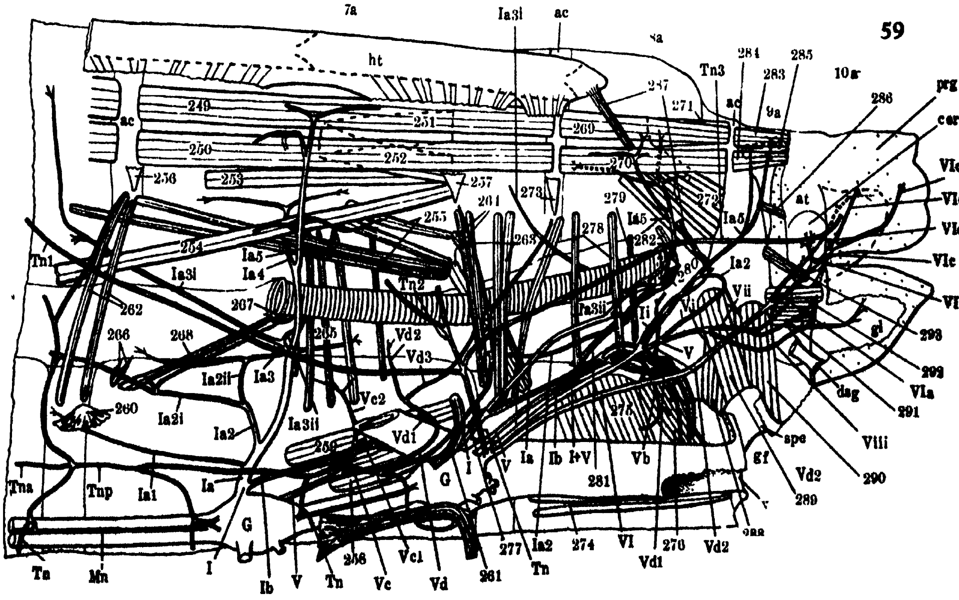
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288

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Errata

Page	Line		
120.	37.	Read	'Ganglia' for 'Ganglions'.
208.	21.	"	" " " " .
120.	42.	"	'Ganglion' for 'Ganglons'.
121.	23,29.	"	'McClendon' for 'Maclendon'.
230.	1.	"	" " " " .
122.	14.	"	'neighbourhood' for 'heibourhood'.
123.	4.	"	'prostomial region' for 'prostomialreion'.
123.	24.	"	'frontal region' for 'frontal-region'.
124,134,) 135,137.)		"	'MacGillivray' for 'Macgillivray'.
126.	29.	"	'well-thickened' for 'well-thickenak'.
137.	24.	"	'furco-entopleural' for 'fuca-entopleural'.
137.	26.)	"	'furco-entopleural' for 'furca-entopleural'.
170.	22,26.)		
205.	2,8.)		
223.	30.)		
240.	8.)		
133.	12.	Omit	'or anepisternum'.
138.	13.	"	'or katepisternum'.
133.	14.)	Read	'dorsal episternal region' for 'anepisternum'.
172.	4.)		
233.	8.)		
138.	15,33.)	"	'ventral episternal region' for 'katepisternum'.
139.	1.)		
254.	28.)		
138.	19,23.	"	'ventral episternal' for 'katepisternal'.
138.	25.	"	'dorsal episternal' for 'anepisternal'.
216.	24.	"	'The median nerve' for 'The median nerves'.
216.	25.	"	'gives' for 'give'.
130.	10.	"	'forms' for 'form'.
206.	7.	"	'D. Metathoracic' for 'D. Mesothoracic'.

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I. INTRODUCTION

The phenomenon of the subterranean fructification (hypogeal development) of the peanut, *Arachis hypogaea* L., is a matter of general knowledge, since MARCGRAF and PISO(13) who were the first to describe the whole plant. According to WALDRON(26), the other plants of leguminosae sharing this peculiarity apart from *Arachis hypogaea* are *Amphicarpa monoica* ELL., *Trifolium subterraneum* L., species of *Voandzeia* and *Kerstingiella*. *Amphicarpa monoica* bears two kinds of flower and accordingly two forms of fruit, only one of which develops underground. The flower which produces the subterranean fruit is formed and always remains underground. *Trifolium subterraneum* bears but one type of flower formed in heads. After flowering the peduncle extends and sinks into the soil carrying the head with it, while the seeds ripen above the ground and will germinate. Unlike both of these, the other two genera mentioned above have a nearly uniform type of flowers, the ovary of which perfectly develops underground.

Analogous facts were also reported in *Falcata comosa Kuntze.* (hog-peanut) by ALLARD(1), in *Falcata comosa Kuntze.* var. *japonica Makino* by MAKINO(12), the former bearing three kinds of flowers, the latter two, in each case respectively only one of which develops underground.

In the case of *Arachis hypogaea,* in the leaf axils along the whole length of the stem, are found certain flowers characterized by a very long calyx-tube; at the top of the flower are situated the calyx, the corolla and the stamens and directly below them the calyx-tube, while at the base of the flower is found the very small ovary. As is well known, after fecundation when the flower has withered and fallen we find that stalk-shaped cylindrical organ called peg or gynophore sprouts out from the leaf axil, and curving downwards penetrates into the ground to a depth of 2-5 cm., after which the top-part, namely the ovary which up to this time has remained dormant, begins to develop into fruit. (Plate I. Fig. 1.)

The problems concerning the subterranean fructification of this plant are of great interest from the standpoint of physiology, morphology, ecology and anatomy. Although most of the recent works on the peanut have been largely concerned with either its culture, uses or chemistry, very few have been concerned with the questions mentioned above, except those of PETTIT(15), VAN der WOLK(25) and WALDRON(26) who, as far as the author is aware, have touched on these problems to some extent. These works, however, gave only a description without critical data. Besides them, REED(16) has reported on the embryology, and KAWAKAMI(10) and HUSTED(8) on cytological research of this plant.

It is the purpose of this paper to present the results of some physiological and morphological investigations specially related to the subterranean fructification, desiring to find, through those results, some fundamental principles bearing upon the reasonable field cultivation of this plant. The author feels, however, that he has made but an outline of the investigation and hopes to pursue it further in the future.

It is a pleasure to acknowledge the invaluable criticism and encouragement given to the author during this investigation by Dr. E. ISO, under whose supervision the work has been done. To Drs. T. MINAMI, and M. AKEMINE the author wishes to express his sincere thanks for helpful advice and continuous encouragement. The author is also indebted to Mr. K. JO, I. KIKUCHI, K. KOBASHI and Mr. S. NAWA for their kind help.

II. MATERIALS AND GENERAL METHOD OF EXPERIMENT

Experiments had been carried on during the summers of 1931, 1932, 1933 and 1934 successively by means of field and indoor experiment, the former in the field of the Experiment Station of Taihoku Imperial University, and the latter in the greenhouse with plants grown in pots. The varieties used were "*Java Tairyu*" (Java large-seeded) for the runner type, and "*Java Shoryu No. 3*" (Java small-seeded No. 3) "*Nagasaya*" (long-podded) for the bunch type, which were all obtained from the Experiment Station of Government General of Taiwan. In most cases, however, "*Java Shoryu No. 3*" was used throughout the experiment except in those cases, where special notice to the contrary is given.

As far as the method pursued is concerned, the fertilizers used were 1129 kg. of compost and 20 kg. of superphosphate per 10 A. on the day before planting; the spacing in the drill was 66 cm. × 45 cm., three or four seeds being sown in each stand, which were thinned down to one later. The time of sowing was the 23rd of April and 23rd of May in 1931, the 9th of March in 1932, the 27th of March in 1933 and the 25th of March in 1934. Some of the plants had been transplanted into pots and put in the greenhouse several days before their flowering in order to use them for indoor experiments.

In showing the results the average number is calculated down to two places of decimals disregarding the residue.

III. REQUIREMENTS NECESSARY TO THE SUBTERRANEAN FRUCTIFICATION OF GYNOPHORES

It is well known that a gynophore does not bear fruit on the ground. For instance, PETTIT(15), WALDRON(26), SPRECHER von BERNEGG(21) and REED(16) state that the ovary is quite inactive and never grows large so long as it remains above ground. Accordingly, when the gynophore fails to reach the ground because the flower is situated too high, it will die. Even when it does not die for a long time, the ovary will begin growth and form an enlargement at the tip and then develop chlorophyll, but it never matures seeds.

According to the experiments made by VAN der WOLK(25) to induce the artificial fructification above ground, all the cases resulted perfectly negative not only when the gynophore was treated in the dark either under the dry or vapour-saturated condition, but also when either it was stimulated by various external pressure or inserted into dry soil, both kept in the dark condition. On the contrary, positive results in fruit-formation were obtained when the soil inserted was kept continually wet and when the gynophore was kept in soil-extract solutions obtained by boiling the soil. From this he concluded that the fructification of the peanut is an activity produced by chemical matter found in the soil which nourishes the gynophore. WALDRON(26) concluded that gynophores placed in a saturated atmosphere and not allowed to penetrate in any substratum, continued to elongate and become green for about a month, and then wilted just back of the ovary. When however the gynophores were allowed to grow in test-tubes of tap water, either kept in the dark, or exposed to the light, he found two of those treated as in the former manner (i. e. growing in test-tube of tap water and in the dark) produced fruit. Moreover, others which were allowed to grow in sphagnum and in pure sand produced positive and normal fruit-formation.

The various investigations mentioned above suggest that the requirements for subterranean fructification after the gynophore has penetrated into ground are (1) absence of light and (2) water. However, the investigations carried out by the authors cited above are merely a description showing few critical and experimental data, and throw no light whatsoever upon the other factors concerned. The present author, therefore, tried to ascertain the factors necessary for the subterranean fructification as minutely as possible on the basis of experimental results.

1. Relation of water to fructification

The author tried to ascertain exactly how far water is necessary for fructification using plants cultivated in the greenhouse. The apparatus devised for this experiment is a test-tube, 1.5 cm. in diameter and covered with a cap, having a hole in the centre, into which the gynophore is inserted. One kind of the tube with its cap is covered with black paper in order to exclude the light, the other is of plain glass. In this experiment, four different kinds of tubes were used as follows:

(1) Black tube without tap water.
(2) Black tube filled with tap water.
(3) Colorless tube without tap water-
(4) Colorless tube filled with tap water.

They were named "black without water", "black with water", "Colorless without water" and "colorless with water" respectively for the sake of convenience, and will be so referred to hereafter.

These tubes were driven into the soil just below the gynophore of the respective plant held in a fixed position, and gynophores were inserted in each of them. The length of gynophore used was selected so as to be as alike as possible lest the fructification might be influenced by the difference in the length of the gynophore; the gynophore was inserted to a depth of 2 cm. from the hole of the cap. Thus by regulating as far as possible the length of gynophore and the depth of insertion in the test-tube it became possible to establish a standard procedure used uniformly in the experiment except in special cases.

The observation were discontinued at the beginning of fructification, i. e. at the stage when the ovary begins to swell in width parallelotropically, arresting the longitudinal elongation of the gynophore (this phenomenon is known as geotropism as will be explained afterwards). In many of the following experiments unless special notice is given to the contrary the observations did not go beyond this stage of development of ovary. (Plate I. Fig. 1., e; Plate II. Fig. 2., c)

The results of the experiment are as follows:

According to these results reached in the course of 30 days, it appears that in the case "without water", whether in dark or light, gynophores stopped their elongation on the 10th day and withered on the 15th day, while on the contrary, gynophore did not wither under "with water" conditions. Fructification, however, takes place only in "black with water", and no fructification is seen in

TABLE 1.

Showing the influence of water on fructification. (1930)

	Nnm-bers tested	Initial length	3rd day clon-gation	5th day elon-gation	7th day elon-gation	10th day elon-gation	15th day elon-gation	30th day elon-gation
		cm	cm	cm	cm	cm	cm	cm
Black without water	5	10.03	3.00	—	2.00	1.0	*	—
Black with water	5	9.50	1.36	0.1	—	-	—	—
Colorless without water	5	8.90	0.80	–	0.30	0	*	–
Colorless with water	5	7.95	1.15	-	0.65	0.95	—	5.9

* indicates those withered.

** indicates the day when fructification begins.

"colorless with water" even after the lapse of 30 days. Gynophores elongate better in the dark than in the light.

At the same time the author used a test-tube, 2.5 cm. in diameter, covered with black paper, on the inner wall of which was put blotting paper to suck up water from the bottom of the tube. Under such conditions of vapour-saturation gynophores were inserted in the tubes, but after 10 days there was not the slightest indication of fruit-forming, though the gynophores elongated extraordinarily and many hairs appeared on their surface. That is to say, no fructification can be seen not only in tubes exposed to the light, but also in the dark either under the dry or vapour-saturated condition.

From this it was possible to reach the conclusion that the most important condition for fructification is that the gynophores should be in contact with water in the dark.

2. Relation between nutrient elements of water and fructification

VAN der WOLK(25) stated that the chemical matter in soil is of great nutrient value to fructification, because. the gynophore bears fruit only in soil-extract solution, but not in rain water. On the contrary, WALDRON(26) asserted that it also can bear fruit in plain tap water. Although it is uncertain to what stage of fructification these two authors refer, the present author has found in his previous experiment (Table 1) that gynophores will bear fruit in tap water at least so far as reaching the first stage of fructification.

The author tried to test further the relation between the nutrient elements in water and fructification. In carrying out his experiment the author compared the result of using KNOP's solution as a nutritious substratum with that obtained by using tap water as a control. In addition to these, the author also observed the case in which use has been made of 5-times concentrated KNOP's solution, so as to make it contain much nutrient. Tap water was used for preparing the KNOP's solution. The apparatus used were black tubes as already explained and plants cultivated in the greenhouse.

In other respects the experiment was carried on in a manner similar to the previous one.

The results of the experiment are shown in Table 2.

TABLE 2.

Showing relation between nutrient elements in water and fructification.

(I, 1931; II, III, 1932)

		Numbers tested	Initial length	Period necessary for beginning of fructificarion	Total elongation	Average elongation per day
			cm	day	cm	mm
I	Tap water	5	5.6	5.0	3.18	6.36
	Knop's solution	5	5.7	5.2	3.40	6.54
II	Tap water	5	4.38	5.7	3.16	5.54
	Knop's solution	5	4.60	6.5	3.99	6.14
III	Tap water	5	5.44	6.0	3.06	5.10
	5 times concentrated Knop's solution	5	5.48	6.8	3.84	5.65

According to the data given above, in the case of the KNOP's solution the requisite time to reach the beginning of fructification was much longer than in that of tap water; this was more marked in the case of a concentrated KNOP's solution. In every case the elongation of the gynophores in the KNOP's solution is much more noticeable than in tap water so far as this experiment is concerned.

Even in the same tap-water cases the inner and outer conditions of each plant, such for instance as the movement of the nutrient element in water and other conditions of growth, may be quite different on fine days from those on the wet and would induce the difference of period necessary in the beginning of fructification and in the elongation of the gynophore.

From a study of the data mentioned above, it appears that a nutrient in water is not only of no use for the beginning of fructification, but even initially checks the development of ovary, that is to say, the more concentrated the nutrient solution is, the greater is the tendency for the fructification to be adversely affected.

The conclusion, therefore, reached by VAN der WOLK(25) that a nutrient in contact water has quite a good effect upon fructification is shown to be contrary to the fact.

3. Relation of osmotic pressure of solution to fructification

That the addition of nutrient elements to water rather retards the initiation of the phenomenon of fructification as seen from the observations made, is explained by the effect of the nutrient itself, but it can also be considered at the same time as due to the concurrence of another factor, namely; the osmotic pressure of water.

In order to ascertain the relation of the osmotic pressure of solution to fructification, the author carried out an experiment using sucrose solution and regulating the osmotic pressure. The sucrose used was the pure one made in Merck, and the solution as well as the tap water used for cantrol were renewed every day in order to prevent it getting stale. The plants used had been reared in green-house while the method followed in the experiment is similar to that previously described.

The following table shows the results of the experiment.

The osmotic value of an 1% sucrose solution is almost twice as

TABLE 3.

Showing relation of osmotic pressure of solution to fructification.
(I, II, 1931; III, 1932)

		Numbers tested	Initial length	Period necessary for beginning of fructification	Total elongation	Average elongation per day
			cm	day	cm	mm
I	Tap water	5	5.98	6.5	3.35	5.15
	5% sucrose solution	5	6.42	7.5	2.76	3.68
II	Tap water	5	5.6	5.0	3.18	6.36
	5% sucrose solution	5	5.9	5.7	2.33	4.09
III	Tap water	5	4.38	5.7	3.16	5.54
	1% sucrose solution	5	6.16	6.0	3.33	5.55
	5% sucrose . solution	5	4.58	7.5	2.74	3.65
	0.5 mol. sucrose solution	5	3.77	—	1.02*	0.15
	1.0 mol. sucrose solution	5	3.56	—	0.14*	0.02

* indicates those which had not yet fructified within one week, the figure showing the total elongation on that day.

great as that of the KNOP's solution, and therefore a 5% sucrose solution has about 10 times the degree of concentration of the Knop's solution, that is, about 0.1 mol.

As seen in the table above (Table 3), in a solution of more than 0.5 mol. no trace of fructification appears during the 7 days and elongation is very scanty.

That the osmotic pressure of the KNOP's solution affects the beginning of fructification has been shown in the former section (Table 2), and the effect is recognized more evidently from the data given above which show that the pressure rises corresponding to the degree of concentration ranging from twice (1% sucrose solution) to 10 times (5% sucrose solution). And in solutions of more than 5% sucrose elongation went on correspondingly weaker. This is considered due to the effect of osmotic pressure of the solution upon the elongation of the gynophore.

The author, moreover, tried to test in what way a higher osmotic pressure delays the beginning of fructification from the anatomical standpoint of ovule development, that is to say, the authcr measured and compared microscopically the width and length of a longitudinal section of the ovules in two ovaries, one of which had been steeped in a 5% sucrose solution and the other in tap water for three days respectively, and in addition to them gynophores of approximately the same length grown above ground were used for purpose of comparison and control. The ovules used had their embryos still dormant and provided only with integuments and nucellus. As the ovary contains two ovules, the author measured them separately, calling the one situated at the end upper ovule, and the other situated at the base lower ovule. These names will be so referred to hereafter. The gynophores chosen for purposes of testing had as far as possible the same length i. e. from 6 to 7 cm. The method adopted in carrying out the experiment was the same as in the former cases.

The materials were fixed in FLEMMING's solution, after having prepared a section of 10 μ by the paraffin method, and dyed it with fuchsine. The results of the experiment are as follows:

TABLE 4.

Showing the effect of osmotic pressure of solution on the ovule development. (1932)

	Numbers	Upper ovule		Lower ovule	
	tested	length	width	length	width
		μ	μ	μ	μ
5% sucrose solution	5	309	226	349	275
Tap water	5	343	253	373	297
Control, above the ground	5	309	221	333	263

According to the above table, the ovule inserted in water is larger than that in sucrose solution, that is, the former is better in development.

The author next pursued an experiment to test the effect of the higher osmotic pressure of the first medium upon the development of an ovule initially inserted in the sucrose solution and then alternated with water. The following table (Table 5) shows the effect upon the ovules transfered into water from the sucrose solution, into which one of them was inserted for one day and the other for three days.

In other respects the method of procedure was similar to that followed in preceding experiments.

TABLE 5.

Showing the effect of higher osmotic pressure of initial medium to fructification. (1932)

	Numbers tested	Initial length	3rd day elongation	Period necessary for beginning of fructification	Total elongation	Average elongation per day
		cm	cm	day	cm	mm
Control (tap water)	5	4.87	1.88	5.8	2.89	4.98
5% sucrose solution, inserted for 1 day	5	4.73	1.86	6.4	2.99	4.67
5% sucrose solution, inserted for 3 days	5	5.98	1.22	7.0	2.53	3.61

According to this table, it appears that the shorter the period during which the gynophore was immersed in the sucrose solution and the sooner it was transfered into water, the nearer its elongation is to control and the shorter time is necessary for fructification to begin. From this point of view it is evident that the high osmotic pressure of the medium checks fructification.

4. Relation of moisture in the soil to fructification

It is evident from the results of experiments mentioned above that water is a necessary element for fructification and that the quality of the water has also some influence upon it. In field observation properly speaking, the moisture contained in the soil seems to have great influence upon the beginning of fructification. VAN der WOLK(35) succeeded in making the gynophore bear fruit in moist soil, but was unsuccessful in dry soil.

For the sake of making clear the relation between soil-moisture and fructification, the author made use of a pot filled with soil, the varying moisture of which was regulated by LIVINGSTON's auto-irrigator; the gynophores inserted in it had been those growing from a plant cultivated in another pot. The tip of the gynophore was buried about 2 cm. deep in the pot and the whole surface of the soil covered by paraffin paper, except for the portion where the gynophore had been inserted, in order to prevent moisture from vapourization. The experiment was carried but in the greenhouse.

LIVINGSTON's auto-irrigator used was the type made by Shimazu & Co. in accordance with the design of Prof. KOYAMA(11) (an irrigator of 5 cm. in height, 7 cm. in lower diameter and 2.5 cm. in upper calibre). The connected tube of hard glass, 3.6 mm. in inside diameter was filled with water cooled down after being boild to prevent air bubbles adhering to the tube wall. The soil was brought from the fields being rather heavy.

The mercury showed 7.72% of moisture in the case of 10 cm. in height, and 13.5% in 3 cm. In another case, the author used a pot, the bottom of which was immersed in the water-tank about 5 cm. in height, by which means, through capillarity, the moiture on the surface of the soil was kept at 22.6%.

The following results were obtained from the experiment.

TABLE 6.

Showing relation of moisture in the soil to fructification. (1932)

Moisture of soil	Numbers tested	Initial length	Period necessary for beginning of fructification	4th day elongation	Total elongation	Average elongation per day
%		cm	day	cm	cm	mm
22.61	6	6.31	4.0	1.14	1.14	2.85
13.58	5	7.18	5.2	1.37	1.92	3.69
7.72	5	5.49	6.3*	1.20	2.13*	3.38

* indicates those showing only $\frac{3}{5}$.

In the third case where the moisture of the soil was 77.2% the number of days for fructification and elongation of the gynophores were observed only in three fifths of the number tested, the rest of them being negative in effect even seven days after the commencement of the test. According to the result, the more moisture the soil contains the better it is for beginning of fructification and accordingly the earlier can it bear fruit. No notice has been taken with respects to the whole plants grown under the same condition of moisture as the gynophores, as the problem concerning the whole plant would be irrelevant to the present experiment.

Therefore, it may be concluded that the rainfall in the period of growth will soften the soil, thus mechanically making easier the penetration of the gynophores into the ground and physiologically stimulated the gynophores to begin subterranean fructification.

5. Relation of light to fructification

As shown in section 1., it is evident that while water is necessary for fructification, at the same time light is a hindrance to it. The purpose of investigations must therefore be to ascertain the degree to which absence of light is necessary, and to what extent even a short interval of light-exposure may be harmful to functification.

To do this the author, after inserting a gynophore into the " black with water ", observed minutely the effect of exposing the gynophore to light for a regular duration, upon fructification. The author pulled the gynophore up from the " black with water " at 9 every morning and kept it for 1, 3 and 5 hours respectively in the " colorless with water ", inserting it again into the former one afterwards, in order to test the effect. The experiment was carried out with plants cultivated in the field. The results are as follows:

TABLE 7.

Showing relation of light to fructification. (1932)

	Numbers tested	Initial length	Period necessary for beginning of fructification	Total elongation	7th day elongation	Average elongation per day
		cm	day	cm	cm	mm
Control	5	5.35	5.8	4.13	—	7.12
1 hour exposure a day	5	5.37	*	—	3.98	5.69
3 hours exposure a day	5	5.44	*	—	2.89	4.13
5 hours exposure a day	5	5.50	*	—	2.69	3.84

indicates those which had not yet fructified within one week.

According to the table given above, the gynophore bore fruit on the 6th day in the control plot, but when it was exposed to light even for a short time every day, no sign of fructification was seen even after a week. Moreover, the longer the exposure, the shorter the elongation.

A week later the author measured the longitudinal section of these ovules in order to compare their development anotomically, and obtained the following results (Table 8). Another gynophore of nearly the same length kept naturally above ground was used as control. The method followed is similar to that described in section 3.

TABLE 8.

Showing relation of light to the ovule development. (1932)

	Numbers tested	Upper ovule		Lower ovule	
		length	width	length	width
		μ	μ	μ	μ
Control, no exposure	5	394	281	527	379
1 hour exposure	5	342	229	392	292
3 hours exposure	5	323	235	352	296
5 hours exposure	5	321	235	952	302
Control, above ground	5	277	212	283	250

The table indicates that all the ovules treated in the experiment are much larger than the one which remained untreated above the ground, and that the ovule in the control plot (no exposure) is decidely larger in size than others, being especially so in the lower ovule. This suggests that the development of the ovule after the penetration into ground begins at first with the lower one, as will be explained in a later chapter.

The fact is also evident that the ovule is smaller in proportion to the duration of its exposure to light. Referring to the evidence of Table 8, therefore, it is obvious that light delays the beginning of fructification, and that such a delay is proportionate to the greater exposure to light.

Next the author war able to observe what process of growth of the gynophore could be seen by the method above mentioned when it was left in darkness after being exposed to light for regular periods during the course of several days.

In this experiment plants cultivated in the field were used, and were treated exactly in the same way as in the previous experiment (Table 7) for period of 5 days, afterwards leaving them in a perfectly "black with water."

The following table shows the results of the experiment.

TABLE 9.

Showing relation of light to fructification, when the gynophore was left in darkness after being exposed to light for regular periods during the course of 5 days. (1932)

	Numbers tested	Initial length	5th day elongation	Period necessary for beginning of fructification	Total elongation	Average elongation per day
		cm	cm	day	cm	mm
1 hour exposure	5	5.81	3.04	6.4	3.75	5.86
3 hours exposure	5	4.96	2.30	7.0	3.34	4.77
5 hours exposure	5	6.44	1.70	8.0	2.74	3.43

According to the table, the elongation of the gynophore during 5 days is inversely proportional to the time of exposure, that is, the longer it is exposed the less it elongates, as the former experiment (Table 7) has proved. When the treatment has ceased by leaving it continually in the dark, it will fructify correspondingly earlier according to the shortness of the period of its exposure to light; the same applies to its elongation.

According to these experiments, it becomes clear that to expose a gynophore to light after being in the dark is very harmful to the beginning of fructification and that the longer it has been exposed the more the phenomenon of fructification will be delayed. It might be suggested that the gynophore should begin to fructify a few days later if the time of the expriment were postponed for a little longer, by exposing the gynophore to the light for a while every day, but such a consideration is beyond the purpose of this experiment.

6. Relation of solar spectra to fructification

As from the former experiment (section 5) it was obvious that the exposure of the gynophore to white light had an adverse effect upon fructification even though it was for a short time, the author intended to ascertain the effect upon fructification in cases where the gynophore was exposed to the light of various wave-lengths. For the experiment the author devised a means whereby it was possible to allow different wave-lengths of light to pass through a glass of test-tube. Weigert(27) describes a method of using a glass plate as to filter various wave-lengths of light by means of colouring it with a pigment solution on which a collodium solution is painted over as film. The author poured rapidly collodium solution on the test-tube, which was covered with thin film of the same thickness. By suecessively pouring a pigment solution prepared under consultation with "Uhler and Wood's Atlas of absorption spectra" on the tube, the author was enabled to measure the passing wave-lengths through the fragments of the test-tube, by means of a Zeiss handspectrometer. The pigments used were Gruber's, dissolved in tap water or 70% alcohol if alcohol-soluble. The author selected accordingly the following four kinds of pigment solution for experiment, using 70% alcohol as a solvent in each. In cases where two pigments are used, one of them is painted on first and the other on the top of it after the previous has dried.

	Pigment solution		Passing wave-length
A.	Chrisoidin	2%	longer than 5300μ
B.	Auramine	2%	longer than 4800μ
C.	Malachite green Methylen blue	1% 2%	5500—4500μ
D.	Gentian violet Methylen blue	1% 2%	5000—4300μ

Filling the test-tubes with water through which light of these four different wave-lengths passes, the author tested them in the field by methods similar to those used in previous experiments. "Colorless with water" passing through white light and "black with water" in dark condition have been added as control. The experimental results are as follows:

TABLE 10.

Showing relation of solar spectra to fructification. (1931)

	Numbers tested	Initial length	Period necessary for beginning of fructification	Total elongation	Average elongation per day
		cm	day	cm	mm
A	15	5.77	13.9	4.83	3.47
B	15	5.44	13.6	5.10	3.75
C	15	6.13	11.7	3.73	3.19
D	15	6.32	11.2	3.09	2.76
"Colorless with water"	15	5.25	—	4.07*	2.71
"Black with water".	15	6.87	5.5	3.35	6.09

* indicates elongation on the 15th day.

Observing the results shown above it appears that fructification requires 5.5 days in the "black with water", but requires twice the days in the other cases, the elongation being proportionately affected. The experiment carried out in "colorless with water" shows no sign of fructification as all previous cases do.

Though there is a difference in the number of days necessary for fructification and elongation among different wave-lengths, it is not right to ascribe the causes to the difference of wave-length only, because the other conditions apart from wave-length are not the same; as for instance inequality in the intensity of light. It is proved however that white light never induces fructification, while, on the other hand, other lights are able to induce fructification even though this occurs very slowly.

7. Relation between deficiency of oxygen in water and fructification

Tests show that the beginning of fructification occurs earlier in tap water than in sucrose or nutrient solutions. Though such phenomena are due to the osmotic pressure of medium, the degree of hydrogen ion concentration or oxygen content in the medium should also be taken into consideration.

The author tried to compare the behavior of water deficient in oxygen with that ordinary water. Tap water was boiled for an hour in a hard flask which was then corked and allowed to cool. It is conceivable that the boiling rejected oxygen to some degree. Both the boiled water and the ordinary one were renewed once a day during the course of the experiment which was carried out in the greenhouse. The results are shown in the following table.

TABLE 11.

Showing relation between deficiency of oxygen in water and fructification.

(I, 1931; II, III, 1932)

		Numbers tested	Initial length	Period necessary for beginning of fructification	Total elongation	Average elongation per day
			cm	day	cm	mm
I	Ordinary tap water	5	5.60	5.0	3.18	6.36
	Boiled tap water	5	5.58	5.4	2.90	5.37
II	Ordinary tap water	4	3.39	5.8	2.56	4.41
	Boiled tap water	4	3.57	6.8	3 94	5.80
III	Ordinary tap water	4	3.64	5.5	4.05	7.36
	Boiled tap water	4	3.89	6.3	4.76	7.56

It is evident that signs of fructification appear in the boiled more slowly than in ordinary water. The difference in elongation, however, is not uniform, sometimes being more considerable and others less.

Though it is conceivable that the difference of rapidity in fructification may be effected by other causes such as pH of boiled water and so on, it is not too much to say that the difference is, in general, related to the oxygen content, that is to say, the presence of oxygen is certainly indispensable to fructification.

When a gynophore is inserted in water, lenticels appear on the surface of it near the water level and especially at the base of the ovary. This shows clearly the metabolic function of gynophore and ovary is vigorous, accompained by vigorous respiration, such as is generally seen in the other plant organs. The lenticels appear on that portion which is most vigorous in growth and feels some difficulty in respiration, such as when, for instance, it is immersed in water. Taken in conjunction with the fact observed above, it serves further to confirm that the presence of oxygen in water is indispensable to fructification.

8. Relation between the depth of immersion of the gynophore and fructification

A tendency has been observed in the course of carrying out the previous successive. experiments, that the depth of immersion of the gynophore into water has an effect upon the rapidity of its fructification. This effect is doubtlessly caused by the water pressure and the oxygen content which differ according to the depth from the surface. In view of this the author tried to obtain exact data as regards this phenomenon. Three groups of gynophore were used for the experiment. The first group was immersed to a depth of 2 cm. below the water level; the second one 5 cm. and the third had its length totally immersed in water. The gynophore used in all groups had an elongation of more than 7 cm., because it was neccessary to choose those which elongated more than 5 cm. in order to be able to immerse them totally. The experiment has been carried out in the field and the results are as follows: (See Table 12, p. 22).

These results show that the deeper the gynophore is immersed in water, the later it fructifies. That is, the first group of gynophores bore fruit first and the second one little later, while fructification occurred latest and the elongation was the shortest in the third group.

If such phenomenon is considered in conjunction with the results of former experiment (Table 11), the conclusion is reached that oxygen is also one of the factors which are necessary for the fructification in addition to water and absence of light, and that a deficiency or

TABLE 12.

Showing relation between the depth of immersion of the gynophore and fructification. (1931)

Depth of immersion		Numbers tested	Initial length	Period necessary for beginning of fructification	Total elongation	Average elongation per day
			cm	day	cm	mm
I	2 cm	4	7.78	4.8	3.20	6.67
	5 cm	5	7.98	6.0	3.16	5.27
	Whole length	4	8.55	8.8	2.28	2.59
II	2 cm	5	7.30	4.6	2.90	6.30
	5 cm	4	7.33	5.8	3.15	5.43
	Whole length	5	8.74	7.4	2.42	3.27

lack of oxygen checks fructification evidently, that is to say, that some suitable quantity of oxygen is indispensable for fructification.

It is generally known that it is desirable in the cultivation of peanut to use lighter soil rather than the heavier. One of the reasons for this seems to be due to the view that the former is more porous and contains much more oxygen than the latter.

9. Summary

The results obtained from the experiments descrived above may be summarized as follows:

(1) Water is an indispensable factor for, and light is harmful to, the initial fructification of the peanut. Gynophores accordingly will wither if deprived of water whether in the dark or exposed to the light; similarly no fruit is born when they are grown even in vapour-saturated condition.

(2) The exposure of the gynophore to light even for a little while induces delay in fructification; elongation occurs much faster in a dark than in a light place, that is to say, the longer the gynophore is exposed to light the less it elongates.

The fructification of the gynophore will be greatly delayed in spectral rays of the different wave-lengths, though ultimately it bears fruit, even if it develops only abnormally. On the contrary no fructification takes place when exposed to ordinary white light.

(3) Nutrients contained in the water are of no use in stimulating initial fructification. The more nutrient the water contains the more it delays the beginning of fructification. It is further true that the osmotic pressure of the medium acts as an obstruction to fructification and elongation of the gynophores.

(4) Gynophores in the soil begin to fructify earlier in proportion to the content of moisture contained in the soil.

(5) Fructification is delayed if oxygen becomes insufficient in the water.

IV. BIOLOGICAL CONSIDERATIONS CONCERNING THE BEHAVIOR OF GYNOPHORE ABOVE GROUND

The requirements necessary for subterranean fructification have been minutely described in the previous chapter. It is also necessary for the gynophore fully to grow and elongate above the ground, before penetrating down into the ground. The author proposes in this chapter to describe his investigations on the behavior of the gynophore above ground.

To plunge the ovary into the soil is the only object of gynophore, the length of the latter being determined by the distance of the flower from the ground. Therefore, the gynophore sprung from the leaf axil of the lower part of the plant, being able to reach the ground sooner, is much shorter in length than that of the upper part; in the same way the length of a gynophore grown from the branch of the runner type is much shorter than that of the bunch type. According to PETTIT(15) the length of the gynophore varies between 5 cm. and 15-16 cm. above the ground, while WALDRON(20) concluded 7½ inches is the maximum length reached. According to SPRECHER von BERNEGG(21) the elongation of the gynophore is very much different at the beginning than at subsequent periods of development, showing an elongation from 2–4 mm. at the beginning and from 5–10 mm. later. PETTIT(15) and REED(16) stated that, the magnitude of the angle formed by the gynophore and the stem is determined by the magnitude of the angle formed by the stem and the earth.

The elongation takes place, according to PETTIT(15), WALDRON(26) and REED(16), at a region of meristematic tissue situated just behind the ovary, the central region forming the pith, and the peripheral the vascular bundle and outer cortex. The tip of the ovary becomes pronounced owing to the elongation and lignification of a group of epidermal cells, which in their development push the base of the style to one side and form a cap analogous to a root-cap. SPRECHER von BERNEGG(21) calls this cap Callus stigmatiformis.

As soon as the gynophore has pierced the ground, one-celled hairs develop on its whited underground position. PETTIT(15), WINTON(28), WALDRON(26) and others consider these hairs as absorptive cells simulating root hairs. PETTIT(15) records the cutting off of the root system of a plant, which lived several days without wilting sufficiently to be readily noticed, and suggests that this phenomenon is due to the absorption of water by the gynophore hairs, adding that the principal function of the gynophore hair is to furnish a supply of food material for the use of the developing fruits. RICHTER(17), however, holds a diametrically opposite opinion due to the fact that he had observed that the hairs were modified with cork. According to WALDRON(26) the gynophore immersed in water produces no hairs.

PETTIT(15) and WALDRON(26) have minutely studied the anatomy of the gynophore. WALDRON remarked: "The bundles of gynophores are strong enough to move materials though they are but small in size". According to SPRECHER von BERNEGG(21) and others, the gynophore grows lenticels on its surface which suggests a prime stage of metabolic function.

DARWIN(4) has shown that the downward growth of the gynophore is not due to negative phototropism, and infers that it is due to positive geotropism. THEUNE(21) confirmed this opinion. WALDRON(26) having found some granules in the lumen of the tip-cells suggests that their presence stimulates positive geotropic movement.

1. Water absorption by the gynophore

As has been shown in the previous chapter the gynophore immersed in water is affected by the qualities of the water, it follows therefore that the development of the gynophore must be very closely connected with its water-absorbing functions. Having already remarked in the introduction to this chapter that the gynophore absorbs water with its hairs which grow as soon as it penetrates into soil, the author tried to test by experimental means whether the gynophore really has or not the function of absorbing water.

For the experiment use was made of a test-tube of hard glass, 3.8 mm. in internal diameter, filled with water, on the outer side of which section paper had been pasted. As a certain amount of water, after inserting the gynophore into the tube, will be absorbed regularly, the section paper is useful for measuring the amount of decrease and, accordingly, for determing the amount of water absorbed by the gynophore. To avoid the error caused by evaporation, the gynophore to be examined together with the test-tube and the whole plant in pot, are covered with a large bell grass, the lower part of which is closed tightly with cotton wool; on the inner wall of the bell is pasted a piece of blotting-paper previously saturated with water. In addition to this a beaker filled with water is set inside the bell to prevent the evaporation. The outer side of the bell glass is covered with black paper to exclude the light. The gynophores chosen are as far as possible uniform in length, that is about 3.0 cm.

A wire as large and long as the gynophore is used as a control, which is placed into a test-tube of the same diameter as the one used for the experiment and treated also in the same manner. The descrease of water in a test-tube with the wire, which is considered as due to the natural evaporation, is deducted from the total decrease of water in the case of the gynophore, so as to find the amount of water absorbed by the gynophore.

The numbers of gynophore tested are five in each case. The results of the experiment shown by the averages are as follows:

TABLE 13.

Showing the amount of water absorption by the gynophore. (1931)

	1st day of insertion	2nd day of insertion	3rd day of insertion	4th day of insertion	5th day of insertion
	cc	cc	cc	cc	cc
Water decrease in gynophore test-tube	0.032	0.022	0.054	0.056	0.050
Water decrease in control test-tube	0.005	0.005	0.003	0.011	0.008
Total volume of absorbed water	0.027	0.017	0.051	0.045	0.042

According to the above table, the loss of water due to the evaporation is hardly recognizable as is evidenced by the result of control test.

The result of the experiment shows clearly that gynophore absorbs only a little water, the amount of absorption being small at first and increasing noticeably from the third day. Since the fact that gynophores grow no hairs when immersed in water, has been proved by WALDRON(26), and also has been directly observed in the author's previous experiments as well as in this, it will accordingly be taken for granted that the gynophore absorbs water directly from the epidermal cells of gynophore when it is immersed into water.

2. Region in which the elongation of the gynophore takes place

REED(16), PETTIT(15) and WALDRON(26) have proved that the region in which the elongation of gynophore takes place is just behind the ovary, but no one of them has as yet located it exactly.

The experiment described below was carried out in order to test whether this view is right or not. The author, first of all, graduated the gynophore with Chinese ink as minutely as possible from the tip of the ovary at its end to its base counting the number of scales from the tip to the base in turns.

As the gynophore grows, the increase in elongation within each graduated section was measured and recorded with the Reading-Microscope made by Shimazu & Co. after a lapse of 24 full hours.

The experiment was carried out in the greenhouse with the following results as shown in the annexed table below:

TABLE 14.

Showing region in which the elongation of the gynophore takes place, (1931)

	Length from tip	Interval between each scale	Variation in length between each scale after 1 day	Elongation after 1 day	Elongation per 1 mm. of gynophore
	mm	mm	mm	mm	mm
1st scale	0.67	0.67	0.79	0.12	0.179
2nd scale	1.23	0.56	0.70	0.14	0.250
3rd scale	2.06	0.83	1.81	0.98	0.181
4th scale	2.43	0.37	2.28	1.91	3.219
5th scale	3.75	1.32	2.42	1.10	0.833
6th scale	4.85	1.10	1.97	0,87	0.791
7th scale	5.54	0.69	0.93	0.24	0.348
8th scale	6.30	0.76	0.91	0.15	0.197
9th scale	7.20	0.90	0.98	0.08	0.088

According to the above table, the region in which the elongation of the gynophore takes place is just behind the ovary at its end, thus agreeing with the results obtained by those who previously carried out similar experiments. The maximum elongation per 1 mm. is found at 2.43 mm. from the tip of the ovary, followed by those observed at 3.75 mm.

That is to say, the region of the maximum elongation occurs between 2 mm. and 4-5 mm. from the tip of the ovary. It may be seen that the nearer it is to its base the less it elongates, and that no elongation is found at a distance of about 7 mm. from the ovary.

3. Period necessary for intital elongation of the gynophore

In the studies so far made, the period at which the gynophore begins to elongate and to express a geotropic curve after the fertilization has not been made clear. For the sake of determing this, 30 flowers fertilized on the same day were tagged and four of them were gathered in turns every day, the length and width of their ovaries and the length of their gynophores were micro- or microscopically measured; at the same time their initial symptoms of geotropism were macroscopically observed. The experiment was carried out in the greenhouse, and the results are as follows:

TABLE 15.

Showing period necessary for initial elongation of the gynophore. (1933)

	Length of gynophore	Length of ovary	Width of ovary
	mm	mm	mm
Initial day	×	0.71	0.25
1st day	×	—	--
2nd day	×	-	—
3rd day	1.60*	1.65	0.53
4th day	2.39	1.63	0.85
5th day	2.78	1.27	0.87
6th day**	8.81	1.43	0.85

* indicates length of only one gynophore, the others not having yet developed.

** indicates beginning of geotropic curve.

From the above it appears that the gynophore elongates only a little on the 3rd day after fertilization, and begins to grow rapidly and exactly on the 6th day, although since the 3rd day it has slightly elongated. On the same day the gynophore shows conspicuous signs of positive geotropism.

The same phenomenon was observed also in 20 flowers in the field, which were tagged simultaneously on the 6th of July 1933; that is, they also began to elongate and show geotropism on the 6th day.

It may be concluded therefore that gynophores begin to elongate and show a geotropic curve on the 6th day after their fertilization.

4. Rapidity of elongation of the gynophore

As far as observations made in the field are concerned, gynophores do not all elongate to the same degree. While they naturally elongate as they progressively develop, the elongation is controlled by external and internal conditions. Temperature and humidity of the atmosphere, light, soil conditions etc. are to be considered as external influences while the portion from where the gynophore grows and the time of growth of the plant etc. are to be considered as internal ones. According to SPRECHER von BERNEGG(21) the gynophore elongates 2-4 mm. a day in the initial period of elongation, but 5-10 mm. a day afterwards.

The author tried to compare the elongation of the gynophore on a dry day and on one that followed a day of a heavy rain when the humidity of soil and the air is denser than usual, using those gynophores just after the beginning of elongation and those in which much longer period had elapsed above the ground.

Three cases were chosen according to the length of the gynophore: in the 1st case the gynophore had elongated 2-3 cm., in the 2nd 5-7 cm. and in the 3rd 9-11 cm. The experiment was carried out in the field with the following results:

TABLE 16.

Showing rapidity of elongation of the gynophore. (1931)

	Degree of elongation of gynophore	Numbers tested	Initial length	Elongation after one day
			cm	cm
Dry day	Long	15	10.15	0.39
	Medium	10	5.89	0.43
	Short	10	2.03	0.72
Wet day	Long	10	10.44	0.68
	Medium	10	6.00	0.94
	Short	10	2.92	1.21

According to the above table, gynophores which are longer in length elongate more slowly above ground than those which are shorter. That is to say, the gynophore does not elongate at the same speed in the different period of its development, but the longer it has been above the ground, the more slowly it elongates, and this suggests the ultimate death of the gynophore.

From the table it is also inferred that the gynophore elongates very much less on a dry than on a wet day. This proves that aerial and subterranean humidity have great influence upon the elongation of the gynophore, as will be shown in the succeeding section (section 6 in this chapter).

5. Maximum elongation of the gynophore

In the former experiment (Table 16) it was seen that gynophores elongate more and more slowly above ground, and would die at last unless they were able to penetrate into the soil; those phenomena are commonly proved by field observations. WALDRON(26) said that the length of the gynophore when it dies depends upon the humidity of the atomosphere. While PETTIT(15) stated that the length of the gynophore, above ground, varies from 5mm. to 16–17mm., WALDRON(26) determined that the maximum of elongation is of 7½ inches. By means of the experiment described below the author tried to ascertain the maximum limit of elongation for gynophores above ground.

30 elongated gynophores were selected which had been kept rather long in the field, and their elongation was measured on alternate days. Their average length at the beginning of the experiment was of 11.8 cm., the experiment ended on the 40th day. Most of them died because they lost their power to elongate and develop, only a few of them surviving.

In the following table the data are arranged on the 10th day, 20th, 30th and 40th in turns in order to show the number and ratio of withered gynophores, the initial length, the final length and the elongation on every tenth day. The final length means the length of such gynophores as survived.

As the initial length is of more than 10 cm. as shown in the above table, the subsequent elongation may be said to be very slow.

The exact final lengths obtained by the gynophores was as follows:

For those withered within 10 days 10.8 cm.—14.6 cm.

For those withered within 11-20 days 11.2 cm.—16.2 cm,
For those surviving beyond 40 days 11.4 cm.—20.8 cm.

TABLE 17

Showing maximum elongation of the gynophore. (1932)

	Numbers counted	Percentage of numbers counted	Initial length	10th day elongation	20th day elongation	30th day elongation	40th day elongation	Final length	Total elongation
		%	cm	cm	cm	cm	cm	cm	cm
Withered within 10 days	9	30.0	11.9	†		—	—	13.1	1.2
Withered within 20 days	5	16.7	11.5	-		-	—	13.8	2.3
Withered within 30 days	0	0	-	—	—	—	-	-	—
Survived beyond 40 days	16	53.3	11.8	2.3	1.0	0.3	0.2	15.6*	3.8

* indicates length on 40th day.
† indicates withered gynophores.

Many gynophores witherd only within 20 days, but those surviving beyond this period continued to live for a long time. The length of those withered is generally below 16 cm., while the surviving ones grow no longer from about the 20th day onward, showing slightly the swelling of ovary. Only one out of the 30 gynophores grew beyond 20 cm., but the others all ceased to grow after reaching 16 cm.. The swelling of the ovary seen in some of the survivors mentioned above is perhaps caused by rain, humidity of atmosphere and shade, i. e. by exclusion of the sunlight. However, there is no corresponding growth nor any development in the embryo in ovule.

So long as the experiment is concerned it may be concluded that the maximum elongation of the gynophore is commonly about 16 cm., and that many wither before they can reach their maximum degree of elongation.

Therefore no fructification takes place in the gynophore grown in the field on a branch higher than 20 cm. in height from the ground. From this it can be inferred why fructification is only found on the lower axil of the branches of erect type and even on the top branches of the runner type. It is believed, therefore, that a moulding made at the proper time is very effective in assisting the soil-penetration of gynophores growing on the higher branches.

6. Relation between atmospheric humidity and the elongation of the gynophore

As shown in section 4 above, the elongation of gynophores varies according to whether the day is dry or wet, even though they have the same initial length. It is possible to consider this from two points of view, namely that due to atmospheric causes or to the humidity of the soil. The soil humidity, however, affects the water content in the plant-body rather than the elongation of the gynophore itself, that is to say, it has only a secondary indirect effect upon the gynophore.

In this experiment the author tried to ascertain the direct effect of the humidity upon the elongation of the gynohore by regulating the humidity in the atmosphere. For this purpose the author used a hard glass-tube of 5 mm. inside-diameter, into which a gynophore was inserted, and the entrance was closed with cotton wool to prevent it being affected by the outer air. The end of the tube was inserted in a glass bottle, containing at the bottom a small quantity of sulphuric acid to regulate the humidity in the tube and bottle. According to Prof. Iso(9), the relation between the degree of concentration of sulphuric acid and the humidity in glass at 35 C. is as follows:

Concentration of sulpharic acid	Humidity in glass-tube
15.5%	90%
29.0%	77%
40.0%	57%

The sulphuric acid used was that prepared according to the Japanese pharmacopoeia. Although the concentration necessarily varies in degree according to the temperature, the author used it as prepared for the purpose of his experiment. A gynophore immersed in a tube saturated with vapour produced by the water was used as a control.

The experiment was carried out in the greenhouse and showed the following results:

TABLE 18.

Showing relation between atmospheric humidity and the elongation of the gynophore. (1931)

	Numbers tested	Initial length	Elongation after 2 days	Average elongation per day
		cm	cm	cm
Water	5	4.65	1.25	0.62
15 5% H_2SO_4 solution	5	4.50	0.70	0.35
29.0% H_2SO_4 solution	5	4.90	0.65	0.32
40.0% H_2SO_4 solution	5	5.20	0.05	0.02

The disadvantages of the above experiment are the probable adverse effect of the gas generated by the sulphuric acid upon the growth of the gynophore and the hindrance to its growth due to enclosing the entrance of the tube with cotton wool, but in effect they proved to be negligible for the purpose of comparison.

According to the above table, the greater the aerial humidity, the more the gynophore elongates, while on the contrary, it elongates only slowly when kept in a dry condition. This fact which has already been proved by the former experiment, is related to the other that although the gynophore elongates very slowly during a continuous period of fine days with strong sunshine, it will elongate much quicker after rain.

The next experiment was carried out in order to see how the soil humidity by affecting the plant-body has an indirect effect upon the gynophore. For this purpose the author used two pots, the one being dry and the other supplied with water. Covering the surface of the soil in the pot with three pieces of paraffin paper one over other to protect the gynophore from the indirect effect of aerial humidity produced by the evaporation of moisture from the soil, the author compared the elongation of the gynophores in the respective pots. The experiment was conducted in the greenhouse.

The results are as follows;

TABLE 19.

Showing relation between soil moisture and the elongation of the gynophore. (1932)

Soil condition	Numbers tested	Initial length	Elongation after 2 days	Average elongation per day
		cm	cm	mm
Moist	10	7.14	1.08	5.4
Dry	10	7.55	0.66	3.3

According to the results shown above, the gynophores of plants grown in the moist soil elongates much faster than the other.

As the aerial humidity and the soil moisture are indispensable elements for the normal elongation of the gynophore, a tolerable amount of rain during the period of its growth is very desirable for a good yield of peanuts.

7. Relation between length of the gynophore and fructification

The length of the gynophores above ground varies from case to case according to the time, earlier or later, of their appearance. Some of the gynophores begin to penetrate into the soil when they are still very short, but some do so for the first time after having considerably elongated proportionately to their distance from the surface of the ground. It is an interesting problem to decide what effect the difference in terrestrial length of gynophores will produce upon the rapidity of their first fructification after penetrating into the soil.

In this experiment three kinds of gynophores were used, namely; a long one, a medium one and a short one, which were inserted respectively into "black with water." The experiment was tried in the field and the results are as follows. The standard of length varies according to the materials and the time of the experiment.

Though there are some numerical difference in the various experiments according to the conditions under which experiment was carried out, there is a common tendency for the longer gynophore to begin to fructify earlier. As shown in the 4th division of the above table, tendency is clearly seen in the case of gynophores initially 13.05 cm. in length to begin to fructify after 2.6 days, while those of

TABLE 20.

Showing relation between length of the gynophore and fructification.
(I, II, 1931; III, IV, 1932)

	Degree of elongation of the gynophore	Numbers tested	Initial length	Period necessary for beginning of fructification	Total elongation	Average elongation per day
			cm	day	cm	cm
I	Long	5	10.7	4.0	2.86	7.15
	Medium	5	5.6	5.0	3.18	6.36
	Short	5	4.1	5.4	4.40	8.15
II	Long	4	10.50	5.5	2.00	3.64
	Medium	4	5.98	6.8	3.35	4.93
	Short	4	3.30	8.3	3.57	4.30
III	Long	5	10.26	5.2	1.64	3.15
	Medium	5	6.18	6.0	2.80	4.67
	Short	5	3.32	6.2	3.96	6.39
IV	Long	5	13.05	2.6	0.29	1.12
	Medium	4	6.56	5.2	2.72	5.23

6.56 cm. begin after 5.2 days. At the same time it is evident that the average elongation per day is not proportionate to the length of gynophore. It may be deduced from those facts that the internal tissue of the gynophore will hasten fructification according to its longer or shorter existence above the ground, and also that the ovule will itself develop above ground.

The author measured the size of the ovules of the gynophores different in length. The method of measurement is the same as that shown in section 3 of chapter III.

The results are as follows: (See Table 21, p. 36).

The above table proves the fact that the ovule will grow somewhat even above ground in accordance with daily growth of the gynophore.

PETTIT(15) and WALDRON(26) have said that the development of ovary above ground is stationary, while REED(16) proved that the fully elongated gynophore will make the tip of the ovary more or less corpulent.

TABLE 21.

Showing relation between length of the gynophore and the ovule development. (1932)

	Degree of elongation of gynophore	Numbers tested	Upper ovule		Lower ovule	
			length	width	length	width
			μ	μ	μ	μ
I	long (7.0–8.5 cm)	5	311	215	311	278
	medium (4.5–5.0 cm)	5	277	212	283	250
	short (2.0–3.0 cm)	5	281	218	275	260
II	long (7.0–8.5 cm)	5	379	239	454	334
	medium (4.5–5.0 cm)	5	306	221	343	275
	short (2.0–3.0 cm)	5	284	218	282	231

From this experiment it became obvious that if the ovary after having developed for a certain period above ground, had obtained the elements promoting fructification, it would have begun to fructify earlier. This, of course, does not alter the fact observed previously, namely that it shows no sign of fructification at all so long as it exists above ground.

The observations made in the course of cultivation in the field that when the terrestrial length of the gynophore is longer, the length of penetration is accordingly shorter, and that, on the contrary, when the terrestrial length is shorter the subterranean length is longer, are also based upon the same principle.

8. Relation between water-treatment of the gynophore and fructification

Gynophores so long as they are above ground, are subjected directly or indirectly to various natural conditions such as rain, moisture from the ground and drought. In the experiments described below the author has tried to discover the bearing of those natural elements, especially water, upon fructification.

Experiment 1.

Gynophores in the field are not subjected to the effect of rain at the same rate. To test this, the author first put gynophores in "colorless with water" for 1, 3, 5, or 10 days respectively, and then successively alternated this with immersion in "black with water". The conditions thus treated were similar to those of gynophores penetrating into the soil after a rainfall.

For purposes of control a non-treated plot was used. The gynophores to be tested were selected of uniform length, as far as possible about 5-6 cm. The experiment was carried out from 15th of June 1932 in the open field.

The results were as follows:

TABLE 22.

Showing relation of water-treatment to fructification, when the gynophores are first immersed in "colorless with water" and then transfered to "black with water". (1932)

Period of immersion in "Colorless with water"	Numbers tested	Length at the time of transfer	Period necessary for beginning of fructification	Total elongation	Average elongation per day
		cm	day	cm	mm
1 day	5	5.58	5.0	3.46	6.92
3 days	5	7.13	4.2	2.22	5.29
5 days	5	7.51	3.6	1.71	4.75
10 days	5	8.53	3.0	0.95	3.17
control, non-treated	5	5.78	5.8	3.90	6.72

According to the table given above, gynophores soaked in "colorless with water" began to fructify earlier, but elongated less than those in control: that is to say, the longer they are soaked in water, the better the condition for fructification.

Immersion of gynophores in "colorless with water" is efficacious for fructification, and consequently rainfall in the field has a good result upon fructification.

The difference in the length of gynophores at the time of transfer even when their initial length is same, as seen in the table above is due to the fact that gynophores elongate much better in water.

The difference of elongation during a period of 10 days between gynophores immersed in "colorless with water" and those in control above ground is as follows:

TABLE 23.

Showing difference of elongation between the gynophores immersed in "colorless with water" and those above ground. (1932)

	Numbers tested	Initial length	Elongation after 10 days	Average elongation per day
		cm	cm	mm
"colorless with water"	5	5.74	2.74	2.74
control, above ground	5	5.50	4.10	4.10

The elongation of the gynophores immersed in "colorless with water" is much less than of those in control above ground, as has been already proved by the experiment described in section 1 of chapter III. Mention has already been made of the fact that the elongation of the gynophore, so long as it is above ground, is proportioned to the degree of aerial humidity, but that the elongation of those in "colorless with water" is considerably less than of those growing naturally above ground. This phenomenon seems to be produced by physiological causes such as excessive contact with water and the respective deficiency in or lack of oxygen, and the osmotic pressure of the solution.

The reason why gynophores soaked in "colorless with water" for a longer period begin to fructify earlier is due to nothing but the development of the ovule. The following table is a comparison of the longitudinal section of the ovules of gynophores. The length of gynophores tested ranges from 6 to 7 cm.

TABLE 24.

Showing difference of development between the ovules immersed in "colorless with water" and those above ground. (1932)

Period of immersion in "colorless with water"	Numbers tested	Upper ovule		Lower ovule	
		length	width	length	width
		μ	μ	μ	μ
1 day	5	290	222	342	289
3 days	5	295	226	361	290
5 days	5	309	232	373	290
10 days	5	373	252	474	395
control, above ground	5	309	221	333	263

The ovule of a gynophore when immersed in "colorless with water" grows larger in proportion to the period of immersion than it does when left naturally above ground.

Though the tests carried out show that no fructification of the gynophore is found while in "colorless with water," the gynophore will be able to begin fructifying faster than ever, when it is inserted in "black with water," because the ovule can grow to some degree even in the "colorless with water" as seen from the above table.

That the velocity of fructification of the gynophore is controlled by the length of the terrestrial gynophore has been proved in the previous experiment. The phenomenon is considered to be due to the development of the internal tissue of the gynophore, as well as to the development of the ovule itself caused by much water during its long period above ground. The reason for the difference in velocity of fructification caused by the difference in gynophore-length that did not appear so clearly in the previous experiment now becomes evident, and is based upon the dissimilarity of the period of its contact with water.

Experiment 2.

The previous experiment shows the result of alternatively plunging gynophores into darkness immediately after having immersed them in "colorless with water." What conclusion, however, can be reached if they are exposed to light before being plunged into darkness? Generally speaking, gynophores do not penetrate into soil immediately after rain, though this does sometimes really occur. The conditions necessary for the beginning of fructification will, accordingly therefore, be different in accordance with the period during which they remain above ground after the rain.

The author, in this experiment, used gynohores immersed in "colorless with water" for 1, 3, 5 or 10 days respectively, and also exposed each of them to light for 1, 3, 5 or 10 days respectively by leaving them in their natural state above ground. After this treatment they were for the first time inserted into "black with water".

The gynophores to be tested were selected of uniform length, as far as possible, about 5-6 cm.. And ones about 5-6 cm. in length, and others of about 8-9 cm. in length which they should elongate during 10 days of "black with water" immersion, were selected as control. The experiment, like the preceding one, was carried out in the open field from 15th of June 1932. As fine weather lasted during the course of the experiment withot any rain, there was no difficulty in comparing the present with the former experiment (Table 22).

The results are as follows:

TABLE 25.

Showing relation of water-treatment to fructification, when the gynophores are first immersed in "colorless with water" and next put in natural state and then in "black with water". (1932)

Period of immersion in "colorless with water"	Period above ground	Numbers tested	Length at the time of transfer	Period necessary for beginning of fructification	Total elongation	Average elongation per day
day	day		cm	day	cm	mm
1	1	5	6.64	5.6	3.44	6.14
	3	5	7.64	5.4	2.97	5.50
	5	5	7.85	4.6	3.12	6.78
	10	5	7.63	5.0	2.58	5.16
3	1	5	7.13	4.4	2.56	5.82
	3	5	6.19	4.0	1.37	3.43
	5	5	7.51	4.0	1.77	4.43
	10	5	8.71	4.2	1.89	4.50
5	1	5	7.79	4.4	1.93	4.39
	3	5	7.79	4.0	2.01	5.03
	5	5	8.98	4.2	2.34	5.57
	10	5	8.74	4.2	2.61	6.21
10	1	5	10.94	2.6	0 79	3.04
	3	5	10.58	2.8	1.23	4.39
	5	5	8.95	2.8	1.17	4.18
	10	5	10.10	2.8	0.29	1.04
control	1.	5	5.78	5.8	3.90	6.72
	2.	5	8.98	5.0	2.37	4.74

In accordance with the above table the results of the experiment can be summarized as follows:

(1) Gynophores exposed to the light above ground after immersion in "white with water" begin to fructify faster and elongate less

as is also the case with those immersed in "black with water" immediately after being plunged in "colorless with water". For instance, non-treated gynophores begin to fructify after 5.8 days, while those immersed in water for a day do so after 4.6–5.6 days.

(2) The longer the gynophores are immersed in "colorless with water", the faster they begin to fructify, but the less they elongate. For instance, those kept in water for a day begin to fructify between 4.6 days and 5.6 days afterwards while those kept in water for 10 days do so after 2.6-2.8 days.

(3) In gynophores immersed in "colorless with water" for the same duration, only a small effect is produced by the period during which they are left naturally above the ground after treatment. Only in the case of water immersion for a day it might seem that the number of days necessary for fructification is slightly shortened, inversely proportional to the period of leaving them above ground under natural condition.

When the former Experiment 1 where gynophores were immersed into "black with water" immediately after their "colorless with water" treatment is compared with the present experiment, no apparent difference can be discovered between them so far as cases of "colorless with water" immersion for 1 day or 3 days are concerned. But in the former the gynophores begin to fructify faster in the case of "colorless with water" immersion for 5 days, while in the latter the gynophores do so faster when immersed in "colorless with water" for 10 days.

Summarizing these experiments, we find that gynophores immersed in "black with water" immediately after "colorless with water" treatment begin to fructify as soon as those which are left in natural condition above ground before immersion in "black with water," although the latter case may be seen occasionally to be more effective in hastening fructification. That is to say, the period during which the gynophores are left above ground in dry condition after rainfall has no useful effect upon fructification.

It may be possible to assert that the element responsible for increasing the size of the ovule of a gynophore above ground is the effect of water. The fact of the length of the gynophore above ground causing earlier or later fructification is to be explained by the gynophore's greater or lesser chance of being exposed to rain.

The rate of elongation of gynophores left above ground and not treated after their "colorless with water" immersion is as follows:

TABLE 26.

Showing rate of elongation of gynophores left above ground after the "colorless with water" immersion. (1932)

Period of immersion before leaving above ground	Numbers tested	Initial length	10th day elongation	Average elongation per day
		cm	cm	mm
1 day in "colorless with water"	5	5.38	2.62	2.62
3 days in "colorless with water"	5	7.57	1.14	1.14
5 days in "colorless with water"	5	7.76	0.30	0.30
10 days in "colorless with water"	5	9.48	0.62	0.62
Control, non-treated	5	5.50	4.10	4.10
Control, in "colorless with water"	5	5.74	2.74	2.74

The elongation of the gynophores left naturally above ground after water-immersion becomes progressively less in proportion to the longer period of water-immersion..

9. Relation between exposure of the gynophore previously penetrated into soil and fructification

Gynophores that have previously penetrated into the soil in the open field, and finding themselves above ground again owing to natural and artificial causes such as raining, winding and technical processes, would be exposed to light, surface dryness and moisture; of those some would be left above ground while some would again penetrate into the soil. In this section the author has attempted to ascertain the relation between gynophores exposed a second time above ground and their fructification.

The gynophores begin to fructify, in general, between the 4th and 6th day after "black with water" immersion, though the period is fluctuated by the terrestrial length of gynophores as has been shown in section 7 of this chapter. This phenomenon is also held good in the field, that is, the gynophores also cease to elongate on 5th-6th day after penetration into the soil, while their ovaries grow bigger.

In this experiment the author artificially buried gynophores, 5-7 cm. in length, into soil to a depth of 2 cm. from the tip and brought 3 groups of them to the earth's surface after being in the soil for 1, 2 or 3 days. The gynophores thus exposed above ground are divided into two groups respectively, one consisting of a certain number of them naturally exposed for 1, 3, 5 or 10 days, and the other of those kept in "colorless with water" for a equal period of time. Alternating them in "black with water" respectively after the days, the author observed the phenomenon of fructification. Two groups of gynophores before penetration in the soil, one of which long and the other short, were added to the experiment as control. The experiment was carried out in the field from 15th of June 1932. As the weather was fine during the course of the experiment when the gynophores were naturally exposed above ground, the experiment was carried out without any difficulty. The initial length shown in the table indicates the length just before the "black with water" insertion, and accordingly, the number of days neccessary for the beginning of fructification are to be counted as from the insertion. The results of the experiment are as follows:

TABLE 27.

Showing relation between exposure of the gynophore previously penetrated into soil and fructification. (1932)

Days in soil	Condition treated	Period of exposure	Numbers tested	Initial length	Period necessary for beginning of fructification	Total elongation	Average elongation per day
		day		cm	day	cm	mm
1	In "colorless with water"	1	5	7.14	4.4	2.62	5.95
		3	5	7.90	4.0	2.35	5.88
		5	5	7.21	3.0	1.75	5.83
		10	5	8.77	2.4	0.44	1.83

Days in soil	Condition treated	Period of exposure	Numbers tested	Initial length	Period necessary for beginning of fructification	Total elongation	Average elongation per day
1	In natural condition	1	5	6.82	4.4	2.80	6.36
		3	5	7.09	4.6	2.52	5.48
		5	4	7.72	4.0	2.26	5.65
		10	4	10.87	4.0	2.24	5.60
2	In "colorless with water"	1	5	7.10	4.2	1.68	4.00
		3	5	7.08	3.0	1.30	4.33
		5	5	7.67	2.4	0.70	2.92
		10	5	7.48	2.2	0.56	2.55
	In natural condition	1	5	7.28	4.0	1.95	4.88
		3	5	7.27	3.8	2.29	6.03
		5	5	7.96	3.6	1.32	3.67
		10	5	7.45	3.6	1.33	3.70
3	In "colorless with water"	1	5	7.82	3.8	1.06	2.79
		3	5	7.69	2.6	0.32	1.23
		5	4	7.55	1.2	0.12	1.00
		10	5	8.24	1.6	0.38	2.38
	In natural condition	1	4	7.00	3.8	1.58	4.16
		3	4	7.21	3.2	1.43	4.47
		5	5	7.63	3.2	1.05	3.28
		10	4	7.11	2.2	0.41	1.86
	control	1	5	5.78	5.8	3.90	6.72
		2	5	5.98	5.0	2.37	4.74

The rate of elongation on the 10th day after the treatment of the gynophores in "colorless with water" and those exposed naturally is as follows:

TABLE 28.

Showing elongation of gynophores, previously penetrate into soil, in "colorless with water" and in natural conditions. (1932)

Days in soil	Condition treated	Numbers tested	Initial length	10th day elongation	Average elongation per day
			cm	cm	mm
1	"colorless with water"	4	6.40	1.88	1.88
	natural condition	4	5.85	5.03	5.03
2	"colorless with water"	5	5.86	1.62	1.62
	natural condition	5	6.48	1.00	1.00
3	"colorless with water"	5	7.70	0.54	0.54
	natural condition	4	7.05	0.04	0.04
control, nontreated	"colorless with water"	5	5.74	2.74	2.74
	natural condition	5	5.50	4.10	4.10

In accordance to the tables given above, the experimental results can be summarized as follows:

(1) The gynophores once penetrated in the soil and again buried after their exposure above ground, whether they have been left above ground in natural condition or immersed in "colorless with water", have a faster fructification than those in control, that have never penetrated into the soil. That is to say, those in control require more than 5.0 days and those treated less than 4.6 days for beginning of their fructification, but the elongation for a day is much greater in those of the control.

(2) Gynophores immersed into "colorless with water" after their exposure above ground begin to fructify faster in proportion to the duration of immersion in "colorless with water" when they are inserted into the "black with water". The same tendency can be seen in those penetrated in the soil for 1, 2, or 3 days respectively.

(3) When gynophores are left in the natural condition after their exposure above ground, the period of exposure has not a great

effect on their period of fructification, especially those penetrated in the soil for 1 day or 2 do not differ much from one another. But in those penetrated in the soil for 3 days, the longer the period of exposure is, the faster is the fructification.

(4) If those having been left on the earth for the same duration of time are compared with each other, it can be seen that the longer they have been penetrated in soil the faster they begin to fructify. The same relation is seen with regards to the elongation for a day. These facts are shown more clearly from the results given in the following table (Table 29) which are derived from the preceding table (Table 27).

TABLE 29.

Compendium of Table 27.

	1 day in soil	2 days in soil	3 days in soil
1 day in "colorless with water"	day 4.4	day 4.2	day 3,8
3 days in "colorless with water"	4.0	3.0	2.6
5 days in "colorless with water"	3.0	2.4	1.2
10 days in "colorless with water"	2.4	2.2	1.6
1 day in natural conditions	4.4	4.0	3,8
3 days in natural conditions	4.6	3.8	3.2
5 days in natural conditions	4.0	3.6	3.2
10 days in natural conditions	4.0	3.6	2.2

There is no difference in the days necessary for initial fructification between cases of natural exposure and those of "colorles with water" immersion when the gynophores have all been left only for a day, but as far as the period of exposure more than three days inclusive is concerned, velocity of fructification in the case of natural exposure is obviously inferior to that in "colorless with water".

(5) The longer the gynophores have been in soil, the lesser is their elongation when they are exposed to the air again.

According to the facts given above, it is clear that the gynophores buried again in the soil fructify faster than those penetrating in the soil for their first time, and that, the longer they remain in soil the faster they begin to fructify. Moreover, when they are subjected to rain during their period of second exposure they begin to fructify somewhat faster, but such a tendency is very rarely noticeable in those exposed in natural conditions above ground.

Referring to the fact that the gynophores which have not penetrated into the soil are able to bear fruit quicker, the more they are subjected to rain, it is possible to say that water will hasten the development of the ovule in the ovary to some degree and have a good effect upon the fructification, whether in the case of gyhophores being above ground or in the case of those exposed for a second time after previously having been in the soil.

One may conclude therefore, that the gynophores exposed to the light again after being buried in the soil are continual to keep the power of growth produced by their first penetration into the soil; that is to say, even when gynophores have been exposed after being in the soil, they still fructify normally when buried again. Moreover, they will be affected to a very noticeable degree in those cases in which during their exposure above ground they were subjected to heavy or a protracted period of rain.

10. Summary

The experiments above described in the present chapter may be summarized as follows

(1) According to many who have previously conducted such experiments the gynophore grows hairs analogous to root hairs after its penetration into the soil, by which it absorbs water. The present

experiment has determined that the gynophore does in reality absorb water through its epidermis in spite of the fact that no hair is found on it after its immersion in water.

(2) The region in which the elongation of the gynophore takes place extends from the base of the ovary to about a distance of 7 mm.; the best region for it is situated at 2-4 mm. No further elongation can be seen in the part near the base of gynophore.

(3) Though elongation of the gynophore begins on the 3rd day after fertilization, the process is still obscure. It progresses rapidly on the 6th day. Geotropic curves begin simultaneously with elongation of gynophore.

(4) Being controlled by the inner and external conditions, the velocity of elongation of the gynophore is not always constant. For instance, aerial and subterranean humidity induce a more pronounced elongation, while in water the elongation is slower than in the air owing to physiological conditions. The gynophore elongates above ground more rapidly when it is still short, but progressively slows down as it grows longer until it ceases at last to elongate.

(5) The maximum elongation reached by a gynophore is about 16 cm., beyond which it is very rare for it to go in the field. Many gynophores wither during their period of elongation, and the survivors show a small swelling of the ovary.

(6) Gynophores kept longer above the ground begin to fructify more rapidly, and elongate not so long when penetrated in the soil. This is due to the development of the ovule in ovary, under the influence of water while above ground.

(7) The more protracted and the greater the rainfall enjoyed by the gynophore above ground the better the ovule develops, thus making a much further elongation of gynophore unnecessary under the ground. Gynophores above ground in dry weather without any rain do not show the development of the ovule. Even when it is left under natural dry condition after being subjected to rain no effect is discernible during the period.

(8) Gynophores exposed above ground again after once having been in the soil preserve the results of the first penetration; i. e. they begin to fructify earlier than in the case or primary penetration. The longer this period in the soil has lasted the shorter the elongation and the shorter the time required for fructification. When a gynophore is subjected to rain or moisture during its terrestrial exposure it begins to bear fruit faster, but if it is left in a natural dry condition during exposure, the period of exposure has no effect on fructification.

(9) The terrestrial elongation of the gynophore after its secondary exposure is inversely proportional to the duration of its primary penetration in the soil.

V. PROCESS OF FRUCTIFICATION

As shown by the previous experiments, the peanut develops the normal swelling of the ovary for the first time after penetration of the gynophore into the soil. And it has also been proved that the ovary and ovule would cease to grow after having reached a certain limit above the ground, and that though the length of the gynophore would exert influence upon the rapidity of initial fructification, it would generally cause the rapid swelling of the ovary as soon as its geotropic action has disappeared, five or six days after its penetration into the soil.

According to PETTIT(15) and REED(16), the depth of soil-penetration of the gynophore is about 2-5 cm., and by unequal growth on the side next to the base of the plant, the ovary takes a horizontal position. They also report that the lower ovule develops first followed successively by the other.

According to WALDRON(26), when the ovary, swollen after its soil-penetration, was exposed again to the air, the presence of the elements necessary for the beginning of fructification is no longer requisite because the ovary continues to develop somewhat in a saturated atmosphere, although this development is somewhat abnormal, while under ordinary greenhouse conditions it turns green and remains only small.

Reed(16) had also studied it embryologically, with special reference to its development before fertilization, but so far there has never been any study made of the development of the fruit after soil-penetration, at least as far as the author is aware.

In this chapter the author proposes to trace its history from the initial state previous to fertilization up to that in which it attains to its full development, and at the same time, to try to describe the results of several interesting experiments referring to its process of development.

1. Development of the ovule before fertilization

The author only measured the ovule in length and width not concerning with embryology because as is known Reed(16) had already done this. As materials, the flower buds grown in clusters on the leaf axils were collected and classified as follows according to the degree of development.

B_1 …………	Minute flower-buds difficult to distinguish from leaf-buds.
B_8 …………	Minute flower-buds but more easily distinguishable from leaf-buds.
B_3–B_5 ……	Slightly swollen flower-buds perfectly distinct from leaf-buds, and still tightly shut.
B_6–B_7 ……	More developed flower-buds but with short calyx-tubes.
B_8–B_9 ……	Flower-buds ready to open in one or two days having elongated calyx-tubes.
B_{10} ………	Flower-buds just opened.

Having fixed these with Flemming's solution, cut in longitudinal section in 10μ by the paraffin method, and dyed them with Heidenhein iron-alum haematoxylin, the author measured them by means of a micrometer. The resulting measurements are as follows:

TABLE 30.

Showing development of the ovule before fertilization. (1931)

	Numbers tested	Upper ovule		Lower ovule	
		length	width	length	width
		μ	μ	μ	μ
B_1	6	80	59	80	61
B_2	8	102	80	99	86
B_3	10	174	110	150	118
B_4	14	198	130	190	146
B_5	10	233	152	222	162
B_6	10	235	163	226	173
B_7	8	237	168	240	176
B_8	8	248	174	254	174
B_9	10	254	166	256	176
B_{10}	10	269	176	267	181

As clearly shown from the above table, the ovule increases gradually in size as it approachs to flowering-period; the upper ovule is a little longer than the lower one though the difference is not very conspicuous and tends to disappear as the flowering period approaches. The lower ovule is, as a rule, broader in width than the upper one.

The figures shown in the above table are of course only relative, for the difference is due in part to the different materials tested.

2. Development of the fertilized ovule above ground

The experiment consisted in tagging a number of flowers on a specified date and comparing the development of the ovules in relation to the number of days elapsed since flowering. The method of measurement it the same as the former (section 1).

The following table shows the results of the experiment.

TABLE 31.

Showing development of the fertilized ovule above ground. (1932)

Period after flowering	Numbers tested	Upper ovule		Lower ovule	
		length	width	length	width
		μ	μ	μ	μ
1 day	10	245	176	250	184
3 days	10	258	175	266	188
6 days	5	270	193	282	211
10 days	5	285	213	289	234

In studying the behavior of gynophores in chapter IV, it was found that the elongation and geotropic curve appeared rapidly on the sixth day after flowering. An identical result was revealed by this experiment.

From the above table it is possible to see that the ovules swell increasingly according to the lapse of time after the occurrence of fertilization above ground. The lower ovule becomes bigger and longer than the upper one, i. e. the former has a recognizable tendency to a more rapid growth. The fact that the ovule increases in size even above ground in proportion to the number of days has already been proved by a comparison of the ovules of gynophores above ground which differ in length from one another (Table 20).

There is, however, a limit of development (Table 17) and no fructification can be found under light-conditions (Table 1, 7, 10) as has been proved in chapter III. The dissimilarity between the number measured on the 1st day after fertilization shown in the above table (Table 31) and that shown in the previous experiment (Table 30, B_{10}) may be due to the difference in the materials tested and in the time of collection.

3. Development of the ovule immediately subsequent to soil-penetration

The ovary begins to grow rapidly five or six days after the gynophore has penetrated into the soil. The author has tried to ascertain experimentally the increase in size of the ovule during this process.

For this purpose, use has been made of gynophores of approximately the same length, i. e. 6–7 cm. of the terrestrial length. To prevent errors arising out of inequality in subterranean length, they were artificially inserted into the soil up to 2 cm. from the end of ovary. A certain number of them were taken out every day, and measured in the same way as those in the former experiment (section I). The experiment was conducted in the field, and the results are as follows:

TABLE 32.

Showing development of the ovule immediately subsequent to soil-penetration. (1932)

Period after soil-penetration	Numbers tested	Upper ovule		Lower ovule	
		length	width	length	width
		μ	μ	μ	μ
Control, above ground	5	275	207	278	240
1 day	5	278	204	290	260
2 drys	5	293	213	305	260
3 days	5	308	219	330	272
4 days	5	315	240	346	293
5 days	5	339	249	382	320
6 days	5	468	320	675	453

In this experiment the signs of fructification are first seen on the 5th, and become very marked on the 6th day. The ovule also suddenly becomes bigger on the 6th day as shown in the table.

The difference of development in size between the upper ovule and the lower appears more obvious after soil-penetration, i. e., the lower ovule grows more rapidly in length and width than the other. This fact suggests the possibility that the lower seed will begin to grow faster than the upper seed in the future, which the author will describe in a later section (section 5 of this chapter).

4. Initial period of embryonic development

Until now the author has shown the process of development of the ovule, above ground or immediately after soil penetration. From an anatomical point of view, however, the so-called process means but the development of the surrounding tissue of the ovule, not accompanied by the development of the embryo within the ovule.

REED(16) in his embryological investigations has not indicated at what time the embryo begins to develop. The author therefore has attempted here to study this by using gynophores of 6-7 cm. in length, and burying them artificially into the soil on a specified date. Removing them subsequently according to the number of days elapsed after penetration, the comparison was made, according to the methods already described in section 1. The illustrations are shown in Plate III. Figures 4, 5, 6 and 7 respectively.

Fig. 4 shows the terrestrial condition, Fig. 5 the subterranean condition on the 5th day, Fig. 6 the subterranean condition on the 9th day and Fig. 7 shows the subterranean condition on the 11th day.

As it clearly appears from these illustrations, the embryo is still dormant at the beginning of fructification, only the embryo mother-cell being slightly divided, as shown in Fig. 5, and, therefore, not different from that on the earth as shown in Fig. 4. The embryo of the lower ovule begins its remarkable division for the first time after a period of eight or nine days from its original penetration into the soil as shown in Fig. 6, and grows rapidly as shown in Fig. 7; that in the upper ovule begins two or three days later than the former as can be seen macroscopically.

5. **Subterranean development of the fruit**

Peanuts are classified according to the habit of growth into two types:—the bunch type and the runner (prostrate). Fruits of plants belonging to the former type, are generally smaller than those of the latter; the number of days necessary for maturing and other details of behavior differ considerably in the two types. The author has tried therefore to compare the process of development of the fruit in the two types. In Experiment 1, the former type is studied and the latter in a part of Experiment 3. As to varieties tested, "*Java Shoryu No. 3*" (Java small-seeded No. 3) was used in the former and "*Java Tairyu*" (Java large-seeded) in the latter case.

It is easy to understand that there should be a difference in development according to the condition of cultivation even in cases where the same variety is used; and this is more especially so as peanuts bear fruit under the soil and have close physical relations therefore with the soil itself. How close this relation is, may be deduced from the fact that sandy soil is the best for peanut culture. "*Java Shoryu No. 3*" is used in Experiment 2 for the purpose of comparing the development of plants cultivated in sandy soil.

As a rule most of the peanut varieties have two seeds in one pod, but some contain even more. The author tried in a part of Experiment 3 to compare the development of plants having pods containing two seeds with those having pods with three seeds. The variety tested, which has three seeds in one pod, is the "*Nagasaya*" (long-podded) and belongs to the bunch type.

Experiment 1. Two-seeded variety in heavier soil

The experiment was carried out in the field on the 20th of June 1931 by tagging some gynophores of approximately the same length, 7–8 cm., and letting them penetrate artificially into the soil up to 2 cm. from the tip. Taking them out of the soil every 5 days after the 15th day from initial soil-penetration, the successive development of the fruit was studied by measuring length, width, volume, fresh weight, dry weight, moisture and oil-contents and so on for both the upper and the lower seeds.

The variety tested was "*Java Shoryu No. 3.*" The measurement was conducted with every fifteen fruits, the averages of which are shown in the table. The general tendency of development will be very noticeable from the results, in spite of the irregular numbers appearing in the table because of the lack of uniformity in the materials used for the experiment (Plate II. Fig. 3.).

The results are shown in Table 33.

TABLE 33.

Showing subterranean development of the fruit of two-seeded variety in heavior soil. (1931)

Period after soil-penetration	Pod			Upper seed			Lower seed		
	length	width	ratio	length	width	ratio	length	width	ratio
days	mm	mm		mm	mm		mm	mm	
15	21.74	10.84	2.01	5.31	2.54	2.09	5.71	3.19	1.79
20	26.58	12.12	2.19	8.43	3.92	2.15	9.07	5.11	1.77
25	26.60	12.45	2.14	13.23	6.77	1.95	12.63	8.05	1.57
30	27.97	12.24	2.29	14.10	7.07	1.99	12.70	7.96	1.60
35	27.46	12.47	2.20	15.58	8.29	1.88	13.47	8.62	1.56
40	27.25	12.23	2.23	15.83	8.59	1.84	13.74	9.02	1.52
45	26.38	12.72	2.07	15.40	8.64	1.78	13.70	9.21	1.49
50	27.66	12.01	2.31	15.91	8.62	1.85	14.04	9.15	1.53
60	26.26	12.30	2.13	15.29	8.59	1.78	13.91	9.38	1.4

TABLE 33. (continued)

Period after soil-penetration	Volume		
	pod	upper seed	lower seed
days	cc	cc	cc
15	1.320	0.021	0.034
20	2.147	0.081	0.132
25	2.267	0.343	0.390
30	2.300	0.389	0.405
35	2.134	0.677	0.603
40	2.100	0.667	0.613
45	2.213	0.733	0.667
50	2.187	0.683	0.677
60	2.250	0.697	0.670

TABLE 33. (continued)

Period after soil-penetration	Fresh weight of pod	Pod shell			Upper seed			Lower seed		
		Fresh weight	Dry weight	Water content	Fresh weight	Dry weight	Water content	Fresh weigth	Dry weight	Water content
days	gr	gr	gr	%	gr	gr	%	gr	gr	%
15	1.305	1.253	—	—	0.022	0.004	84.09	0.030	0.005	84.03
20	2.004	1.791	0.170	90.51	0.081	0.014	83.32	0.132	0.027	79.46
25	2.033	1.300	0.255	80.38	0.344	0.093	72.88	0.368	0.117	70.00
30	1.983	1.205	0.282	76.60	0.383	0.116	69.71	0.395	0.136	65.57
35	2.021	0.798	0.281	64.79	0.643	0.262	59.25	0.580	0.241	58.45
40	1.949	0.665	0.287	56.84	0.669	0.357	46.64	0.615	0.333	45.85
45	1.994	0.658	0.288	56.23	0.683	0.399	41.58	0.653	0.387	40.43
50	1.947	0.574	0.271	52.79	0.707	0.427	39.60	0.666	0.403	39.49
60	2.025	0.660	0.287	56.52	0.689	0.435	36.87	0.676	0.429	36.54

TABLE 33. (continued)

Period after soil-penetration	Thickness of testa		Oil content			
			Upper seed		Lower seed	
	Upper seed	Lower seed	in fresh weight	in dry weight	in fresh weight	in dry weight
days	mm	mm	%	%	%	%
15	0.50	0.57	0.79	4.93	0.97	6.07
20	0.78	0.77	2.30	13.76	3.84	18.71
25	0.65	0.52	—	—	—	—
30	0.60	0.56	10.49	34.63	13.25	38.47
35	0.57	0.55	17.91	43.96	20.31	48.88
40	0.45	0.38	27.29	51.14	29.04	53.62
45	0.37	0.25	30.36	51.97	32.91	54.04
50	0.23	0-22	31.26	51.76	32.32	53.41
60	0.28	0.21	33.60	53.23	35.15	55.39

In accordance with the above table the results of the experiments can be summarized as follows:

(1) The pod becomes mature changing in grey color approximately after fifty-days.

(2) The pod becomes suddenly bigger after the beginning of fructification and it attains its maximum length and width approximately on the 20th day. Accordingly the ratio of length to width remains unchangeable hereafter, preserving the balance, and the volume also shows an analogous tendency. The fresh weight of the pod remains unchanged from the 20th day; the weight of the pod-shell decreases gradually from the 20th day onwards, but remains stationary from about the 40th day. The dry weight is much the same from the 30th day onwards.

(3) The lower seed having to grow faster than the upper one, the length or width, volume, fresh weight and dry weight are much superior in the early stage. The upper seed however gets suddenly bigger and becomes longer than the lower one about the 25th day. As far as the present experiment is concerned, the upper seed exceeds in volume the lower one about the 35th day. The upper seed, however, is more moist, and less wide than the lower. As already shown in the previous experiments (section 3, section 4) the latter phenomenon holds continually good before the beginning of fructification.

(4) The seed attains its maximum length on the 35th day or thereabouts, and the width on the 40th day or so. The ratio of length to width diminishes with the lapse of time, which may be caused by the difference of time in attaining maximum length and width. So far as volume and fresh weight are concerned the upper seed becomes suddenly big and heavy about the 25th and the lower about the 20th day. Both attain the maximum volume and fresh weight about the 40th day. The dry weight of the seed increases, but the moisture grows proportionally less as the days pass.

(5) The testa becomes gradually thinner, while the testa of the upper seed is generally more thick than that of the lower.

(6) The oil-content increases gradually; the lower seed is, however, inclined to contain more oil than the upper one.

In conclusion it appears that the outward form of the pod attains its maximum development on or after the 20th day, and the lower seed in the pod begins to grow first. This phenomenon is already referred to by PETTIT(16) and REED(16) as already mentioned and is clearly proved by the observations reported in the former section (section 4) concerning the beginning of embryo-division. The lower seed suddenly becomes bigger on the 20th day or so, the upper on the 25th day and thereabouts. Finally the upper seed from the 35th day becomes superior to the lower seed in volume, fresh weight and dry weight. The lower seed however has a thinner testa and less moisture and higher oil-content than the upper ones on the other hand. It is able to assert consequently that the latter reaches more perfect stage of development, even though smaller in size, than the former.

Experiment 2. Two-seeded variety in sandy soil

As the peanut bears fruit under the ground, the growth of the pod and of the seed are supposed to be influenced mechanically by the surrounding soil. The author tried to ascertain the difference in development between plants growing in clayish soil (ordinary field soil) and those in the sandy soil. For the latter purpose, the field containing sand brought from the river, used for the cultivation of vegetables in the former year, was selected. The method of culture adopted in the two kinds of soil was in accordance with general experimental methods, and carried out under the same conditions. The variety tested was "*Java Shoryu No. 3*"; the same method of investigation was followed as that in Experient 1. The materials tested had been tagged on the 8th of July 1932.

The results were as follows and show the average figures for each pod and seed. (See Table 34, p. 60.)

According to the table given above, the following summary may be given:

(1) The growth of pod and seed is greater in sandy soil than in clayish soil, those in the former proving to be superior in

TABLE 34.

Showing subterranean development of fruits of the two-seeded varieties in clayish as well as sandy soil. (1932)

	Period after soil-penetration	Pod			Upper seed				Lower seed			
		length	width	volume	length	width	volume	dry weight	length	width	volume	dry weight
	days	mm	mm	cc	mm	mm	cc	gr	mm	mm	cc	gr
Ordinary clayish soil	15	22.64	12.24	1.867	7.55	3.35	0.053	0.009	7.72	4.71	0.167	0.021
	25	25.85	12.82	2.133	10.73	5.12	0.188	0.041	11.00	6.60	0.281	0.083
	35	25.17	13.14	1.980	13.82	8.03	0.547	0.248	12.63	8.23	0.560	0.263
	40	24.48	12.69	1.887	14.45	7.78	0.567	0.339	12.77	8.73	0.580	0.347
	45	26.77	13.43	2.353	15.56	8.16	0.660	0.373	14.33	9.08	0.680	0.391
	50	28.74	13.55	2.467	16.01	8.57	0.773	0.517	15.19	9.98	0.833	0.547
Sandy soil	15	25.18	12.10	2.013	7.01	2.68	0.027	0.007	7.85	4.17	0.068	0.012
	25	27.16	13.09	2.380	13.05	6.43	0.347	0.093	12.27	7.44	0.378	0.117
	35	27.59	12.56	2.167	15.46	7.42	0.580	0.255	14.49	8.67	0.620	0.394
	40	27.69	12.84	2.200	16.09	7.92	0.680	0.360	14.49	8.62	0.680	0.368
	45	28.84	13.30	2.393	16.17	8.44	0.733	0.415	14.92	9.55	0.793	0.461
	50	31.05	14.15	3.000	17.84	8.79	0.860	0.573	16.02	9.84	0.920	0.563

length, width, volume and dry weight to those in the latter. It is clear that such phenomena are caused by the physical and physiological properties of sandy soil upon the growth of the fruit.

(2) The growth in clayish soil is much the same as that shown in the former year (Experiment 1).

(3) Special notice should be taken of the fact that, the lower seed is in this experiment superior in volume and dry weight and is inferior in length to the upper whether grown in sandy or in clayish soil in spite of the fact that the upper seed has been proved in Experiment 1 to be superior in its development to the lower. The remarks concerning the differences between those two phenomena will be continued in the later section 7 of this chapter.

Experiment 3. Three-seeded and prostrate varieties

There are varieties of peanut having as a rule several seeds in each pod. What relation have the differences in the number of seeds to their development? Is there also any difference between the fruit development of the runner type and that of the bunch type? In 1932 the author had carried out several experiments in order to investigate these points. The varieties tested were "*Nagasaya*" of the bunch type having three seeds in a pod and "*Java Tairyu*" of the runner type. The method pursued was the same as in the case of Experiment

TABLE 35.

Showing subterranean development of the fruit of three-seeded variety. (1932)

Period after soil-penetration	Upper seed				Middle seed				Lower seed			
	length	width	volume	dry weight	length	width	volume	dry weight	length	width	volume	dry weight
days	mm	mm	cc	gr	mm	mm	cc	gr	mm	mm	cc	gr
15	4.51	1.96	0.013	0.002	8.48	4.50	0.107	0.020	11.62	6.45	0.267	0.055
25	11.09	5.19	0.253	0.066	12.44	7.08	0.367	0.116	12.40	7.76	0.433	0.147
30	13.12	6.53	0.367	0.094	13.75	7.99	0.467	0.143	12.90	8.56	0.487	0.163
35	15.12	7.49	0.587	0.245	14.28	8.26	0.573	0.263	13.77	9.05	0.667	0.304
40	14.87	7.44	0.593	0.253	13.81	8.26	0.560	0.260	13.53	8.95	0.667	0.303
45	15.13	7.85	0.673	0.311	14.22	8.18	0.580	0.269	13.26	8.94	0.600	0.275
50	15.89	8.06	0.680	0.367	13.95	8.21	0.593	0.287	13.54	9.00	0.640	0.332

TABLE 36.

Showing subterranean development of the fruit of prostrate variety. (1932)

Period after soil-penetration	Pod			Upper seed				Lower seed			
	length	width	volume	length	width	volume	dry weight	length	width	volume	dry weight
days	mm	mm	cc	mm	mm	cc	gr	mm	mm	cc	gr
15	29.35	15.18	3.133	6.53	2.41	0.027	0.004	11.35	5.38	0.160	0.033
25	36.32	16.28	4.600	16.29	6.06	0.433	0.085	16.62	9.00	0.743	0.191
30	37.31	17.75	5.300	20.53	8.50	0.873	0.218	17.72	9.59	0.933	0.282
35	37.87	17.47	5.600	20.15	8.98	0.973	0.260	19.00	10.27	1.060	0.307
45	38.45	17.32	5.433	22.05	9.23	1.193	0.431	20.05	10.34	1.273	0.547
50	37.61	16.22	5.266	22.26	9.38	1.140	0.544	19.34	9.12	1.047	0.507

2. They were tagged and buried in the soil on the 8th of July 1932. The results found for the variety having three seeds are shown in Table 35 and those for the runner type in Table 36, in each case the figures giving the average per fruit.

The following summary may be given concerning the variety "*Nagasaya*" from the figures shown in the above table:

(1) Growth begins first in the lower seed, followed by the middle and then the upper.

(2) As far as length of the seed is concerned, the middle seed becomes superior to the lower one on the 25th day; the upper seed becomes superior to the lower on the 30th day and to the middle on the 35th day; i. e., the upper seed is the longest, followed by the middle and the lower, but on the contrary, the lower seed is largest in width, followed by the middle and the upper which is the smallest.

(3) Initially the lowest seed has the largest volume, followed by the middle and the upper in sequence, but on the 35th day the upper seed outstrips the middle one and on the 45th day it also overtakes the lower; i. e. the upper is the largest, the lower comes next and the middle is the smallest.

(4) As far as dry weight is concerned, at the beginning an analogous progression of lower, middle and upper was also found but 45 days later the order changed as to upper, lower, and middle, because the upper becomes the heaviest on the 45th day and the middle the lightest.

From the data given above it appears that the lower seed begins first to develop. Although the middle seed begins at the outset to develops immediately afterwards, the essential development in the matter of volume and dry weight becomes retarded later by the pressure of the lower and the upper seeds. In this experiment the upper seed was found to outstrip the lower one at the end thus coming to rank first among the three. The order mentioned above may however be changed by such oonditions as soil and climate, as shown in the case of "*Java Shoryu No. 3*".

In the case of the runner type lower seed always develops best and is never exceeded by the upper. The following table (Table 37) shows the results of experiment which was carried out in the previous year (1931) with twelve matured pods of "Java Tairyu" and proves that the upper seed, in general, is lighter in weight and lesser in volume than the lower, and that this fact does not fluctuate according to the environment as in the case of "*Java Shoryu No. 3*".

TABLE 37.

Showing difference of development of the upper and lower seeds of prostrate variety. (1931)

	Air dried weight	Volume	Water content
	gr	cc	%
Upper seed	7.7	8.4	8.0
Lower seed	8.3	9.3	7.6

6. Numerical increase of the fruits in connection with the growth of the plant

Here the experiment attempted by the author aimed at ascertaining the numerical increase of the fruits in connection with the growth of the plant.

The plants tested were those sown on the 23rd of April 1931. Nine weeks after the sowing (or 31 days from flowering), five plants were taken out every week from the soil. The fruits borne by the plants were divided into four stages, viz: matured fruit, non-matured fruit, subterranean gynophore and terrestrial gynophore.

The characteristics of each stage are as follows:

Matured fruit	Pod becomes hard and coloured, and shows net-like veins on the surface.
Non-matured fruit	Length of pod grows more than 1 cm.
Subterranean gynophore	Length of pod is less than 1 cm., in spite of having penetrated into the soil.

Terrestrial gynophore.........Those before soil penetration.

The average results per plant are shown in the following table:

TABLE 38.

Showing numerical increase of the fruits in connection with the growth of the plant. (1931)

	Weeks after sowing								
	9	10	11	12	13	14	15	16	17
Matured fruit	0.0	0.0	4.6	15.4	22.0	30.4	39.2	46.2	51.2
Non-matured fruit	10.4	18.2	16.4	22.2	27.4	25.2	32.2	30.0	33.6
Subterranean gynophore	30.0	39.8	35.6	36.8	33.4	48.4	62.2	48.8	46.6
Terrestrial gynophore	21.8	29.6	32.2	42.4	54.8	66.4	112.8	119.2	133.0
Total	62.2	87.6	88.8	116.8	137.6	170.4	246.4	244.2	264.4
Total subterranean fruit	40.4	58.0	56.6	74.4	82.8	104.0	133.6	125.0	131.4
Total subterranean versus total (%)	65.0	64.2	55.9	46.9	40.0	39.0	34.9	28.6	26.6
Matured versus total subterranean (%)	0.0	0.0	8.8	26.1	36.2	41.3	41.5	58.6	63.8
Matured versus total (%)	0.0	0.0	5.2	13.2	16.0	17.8	15.9	18.9	19.4

The following summary may be drawn from the above table:

(1) Matured fruits, non-matured fruits, subterranean gynophores and terrestrial gynophores all increase in number as the plants increasingly mature. The subterranean gynophores, however, do not change in number so remarkably, because the gynophores which have penetrated early into soil immediately pass into the next stage while the number of terrestrial gynophores which take their place and penetrate into soil is comparatively small.

(2) Therefore, the number of fruits under the ground and the total increase day by day as they approach to the mature stage.

(3) The ratio of the total subterranean number to the total number decreases gradually, because the terrestrial gynophores in penetrating into the soil decrease as they approach the final period of growth. This explains why gynophores in the earlier period of growth have a higher fructification rate and play an important

role in the technique of peanut culture. But, on the contrary, the matured fruit is seen to increase gradually in number if compared with the total number or the subterranean number. This proves that when once the gynophores have penetrated into the soil they have a high probability of attaining complete fructification.

7. Artificial changes in size and weight of seeds in the pod

According to the researches conducted in 1931 (Table 33) as to the development of fruit in the bunch type, the upper seed in the pod becomes larger in size and weight than the lower from about the 35th day, although it was much smaller than the latter at the outset. But, in the experiment upon the development of the seeds conducted in 1932 (Table 34) such phenomena were not found, because the upper seed never exceeded the lower. The fruit produced in sandy soil also showed the same result.

In the present experiment the author has tried to discover the causes responsible for these changes in the size and weight of the seeds according to the position in the pod. The experiment was carried out on the 13th of June 1933 with the same variety as used in the experiments above described. Removing the ovaries from the soil 15 days after their initial soil-penetration (Plate II. Fig. 3. c), they were divided into two groups according to whether the upper portion of the pod was made to face (1) downwards or (2) upwards. The pods were in both cases subsequently buried anew in the soil for 35 days, i. e. 50 days after their initial soil-penetration, after which they were once more taken out and the from and weight etc. of the pods and the seeds belonging to each group were compared with one another. Each group consisted of 15 pods. The following results of the experiment show the average figures per fruit.

TABLE 39.

Showing artificial changes in size and weight of seed in the pod. (1933)

		Length	Width	Volume	Fresh weight	Dry weight	Water content
		mm	mm	cc	gr	gr	%
Facing pod upwards	Pod	24.59	11.74	1.686	1.431	—	—
	Upper seed	13.24	7.46	0.467	0.400	0.228	43.00
	Lower seed	13.05	8.35	0.617	0.550	0.303	44.91
Facing pod downwards	Pod	24.66	11.53	1.800	1.686	—	—
	Upper seed	12.93	7.99	0.600	0.595	0.340	42.86
	Lower seed	12.87	8.49	0.540	0.547	0.320	41.50

According to the above table, the upper seed is longer but not so wide as the lower seed wether in the case of the facing the pod upwards or downwards. This phenomenon has already been tested in the former experiment upon the development of the fruit. As far as volume, fresh weight and dry weight are concerned the upper seed is inferior to the lower in the case where the pod faces upwards, but the upper is superior to the lower in the case where the pod faces downwards: i.e. the lower seed grows larger in the former case, and the upper seed develops more in the latter. As mentioned above, the position of the pods under the ground has an effect upon the ratio of growth between the upper and the lower seed. It is clear therefore that the seeds located on the lower side are generally larger than those on the upper side, no matter whether they may happen to be upper or lower seed in the pod itself.

This phenomenon seems to be connected with the translocation of the nutrient elements in the tissue.

Though the differences above mentioned between the results of two experiments carried out in 1931 and 1932 may be produced by various factors, the fact deduced from the present experiment may be counted as constituting one of the important factors.

It may be possible to infer from those results that physiological causes such as the soil conditions and oxygen content in the soil, and mechanical causes such as subterranean obstructions may bring about changes not only in the development of the ovary and seed themselves, but also the position of seeds in the pods executes certain influences on their development.

8. Exposure of subterranean fruits to the light

The observations carried out in the field prove that the fruit grown under the soil would by reason of various causes become green after they had been exposed to light above the gronnd. How the pods and seeds will grow under such condition is a very important problem for the technique of peanut cultivation.

According to the experiments made by WALDRON(26), when the ovaries which swelled under the soil are exposed, whether in an atmosphere saturated with vapour or under greenhouse conditions, they change their colour to green. But while those in the former case can grow somewhat, those in the latter case cease to grow. He also shows that a thigmotropic, hydrotropic or apoheliotropic stimulus, or a combination of these, is necessary for the ovary to begin maturing, but that a continuation of such stimulation is not required after it has begun to develop.

In his experiment, however, no numerical data were given. There is, naturally, some difference in the process of development between ovaries that have swelled underground, i. e., not all of them grow to the same extent. The author has therefore tried here to obtain as exact numerical data as possible with regards to the points mentioned. The experiment was conducted in the field, taking soil-penetrated ovaries located at the base of the plant and selecting out of them two kinds showing different degrees of growth (Plate II. Fig. 3). The observations made as regards the two kinds selected are as follows:

(1) Pods in a relatively early stage of growth ....
Those on the 8th day or so after soil-penetration, have about 1.5 cm. in length.

(2) Pods in an intermediate stage of growth ....

Those on the 15th day or so after soil-penetration, have about 2.2 cm. in length. These were treated by the following methods:

a. Exposed under natural conditions above ground for 10 days.
b. Exposed in "colorless with water" above ground for 10 days.
c. Exposed under natural conditions above ground for 5 days. and afterwards buried in the soil for 5 days.
d. Exposed in "colorless with water" above ground for 5 days, and afterwards buried in the soil for 5 days.
f. Exposed in "colorless with water" above ground for 1 day, and afterwarwards buried in the soil for 9 days.

In other words the author observed the differences in growth of the pods after 10 days under a set of different conditions of exposure above ground. The symbols used above are adopted for the sake of convenience to indicate the various treatments hereafter described. The experiment began on the 29th of June 1932; fifteen pods were used in each case. The items compared show the difference in growth between the ovules and the difference in length and width between the pods. For purposes of control, the pods taken on the day of treatment, and those previously buried in the soil for 8 days and for 15 days respectively, which had not been treated and had remained in the soil for 10 days respectively, were used.

As no rain occurred during the experiment no difficulty was found in comparing those in a natural condition with those in "colorless with water."

In the first the results of the experiment with respects to the pods which have reached an intermediate stage of growth about the 15th day after soil-penetration are shown as follows in an average figure per each fruit: (See Table 40, p. 69.)

The results obtained may be summarized as follows:

(1) a and b show no increase of shell-weight as compared with 0.200 gr. in the control; the length and width of pod also are not better than those before treatment. In c and d the shell weight shows a tendency to increase no less than the length

TABLE 40.

Showing the effect of exposure of subterranean fruits to light, when they have reached an intermediate stage of growth. 1932)

	Before treatment		Development after 10 days											
	length of pod	width of pod	Pod		Dry weight			Volume		Upper seed		Lower seed	
			length	width	pod shell	upper seed	lower seed	upper seed	lower seed	length	width	length	width
	cm	cm	cm	cm	gr	gr	gr	cc	cc	cm	cm	cm	cm
*Control, (initial)	2.25	1.27	—	—	0.200	0.005	0.010	0.027	0.047	0.68	0.40	0.63	0.27
a	2.26	1.22	2.27	1.22	0.195	0.022	0.069	0.087	0.247	0.79	0.37	1.04	0.63
b	2.25	1.27	2.28	1.22	0.195	0.023	0.053	0.107	0.220	0.80	0.43	0.97	0.63
c	2.20	1.19	2.26	1.21	0.200	0.032	0.065	0.120	0.240	0.90	0.50	1.11	0.69
d	2.39	1.21	2.56	1.26	0.218	0.031	0.060	0.113	0.233	0.89	0.39	1.01	0.61
e	2.21	1.26	2.32	1.29	0.227	0.033	0.075	0.153	0.267	0.87	0.50	1.09	0.71
f	2.33	1.24	2.51	1.25	0.227	0.038	0.072	0.167	0.267	1.04	0.50	1.07	0.65
Control, nontreated (25 days after soil-penetration)	—	—	2.59	1.28	—	0.041	0.083	0.188	0.281	1.07	0.51	1.10	0.66

* Results of control plot (initial) are conveniently indicated in the column showing the results after treatment.

and width of the pod as compared with figures before treatment. However, the difference between the two cases before and after the treatment becomes more noticeable in e, f, especially in the controlled case of no treatment, which becomes the longest and widest. It follows therefore that when a pod is exposed above ground, whether in " colorless with water " or under natural conditions, the shell-weight, and its length and width do not increase, i. e., it will not grow bigger and heavier. But when it is buried again into the soil these (shell weight, length, width) begin to increase as before. The shorter time it is left above ground and the longer it is kept in the soil, the more remarkable their development.

(2) From the standpoint of development of the seeds in the pod, on the contrary, both the upper seed and the lower develop tolerably their dry weight, volume, length and width. This development can be observed macroscopically. As far as the degree of development is concerned, those buried in the soil for a longer time, develop more noticeably, especially in the controlled case of no treatment. But the difference of development between those left in " colorless with water " and those left exposed under natural conditions is not obviously recognizable.

It can be concluded from these results that when the pod is exposed above ground on the one hand the shell does not grow larger, while on the other the seeds in the pod are able to develop. It is also true that the pod ond seed would grow normally if they were again buried in the soil after their exposure to the air and light.

In the second place the results of the experiment upon ovaries about the 8th day after soil-penetration, that is, not very long after the beginning of their development, are as follows giving the average figure per each fruit: (See Table 41, p. 71.)

With regard to the development of the seed, the length, width and volume of the ovule were excluded from the above table because it was to too small to measure. According to the table the development of the shell exposed above the ground is much the same as that shown in the former table (Table 40). Observing the develop-

TABLE 41.

Showing the effect of exposure of subterranean fruits to light, when they are in a relatively early stage of growth. (1932)

	Before treatment		Development after 10 days				
	length of pod	width of pod	Pod		Dry weight		
			length	width	pod shell	upper ovule	lower ovule
	cm	cm	cm	cm	gr	gr	gr
*Control, (initial)	1.54	0.85	-	—	0.066	0.0005	0.0015
a	1.55	0.87	1.60	0.90	0.067	0.0008	0.0017
b	1.57	0.90	1.62	0.89	0.065	0.0005	0.0023
c	1.41	0.82	1.59	92	0.091	0.0017	0.0030
d	1.65	0.90	1.89	1.02	0.106	0.0012	0.0044
e	1.41	0.83	1.67	0.96	0.095	0.0078	0.0120
f	1.50	0.86	1.78	1.01	0.111	0.0037	0.0127
Control, non-treated (18 days after soil-penetration)	—	—	2.35	1.24	—	0.0135	0.0310

* Results of control plot (initial) are conveniently indicated in the column showing the results after treatment.

ment of the seed as regards its dry weight, we find that the upper seed on the day of treatment has 0.0005 gr. and the lower 0.0015 gr., but in a and b there is no trace of development, only the lower seed in b having exceptionally grown a little. This exceptional growth may be caused by averaging the weight of seeds tested, some of which exceptionally, grow larger. Their development is recognized for the first time in the case of c, d, e and f, those which have been buried in the soil for a longer time showing a higher degree of development.

But the development seen in those cases is much inferior to that in the controlled case of no treatment.

It may be concluded from the results given above, that when the pods of a peanut are exposed above ground, those which have been growing to a certain extent under the ground allow the seeds in them to develop, while the seeds in those which have not grown to that extent, to the length of 1.50 cm. or so, about eight days later after the soil-penetration, no longer develop. The fact had been proved that it is of no advantage to the gynophore in penetrating into the soil to expose them to the light before the beginning of fructification. The exposure above ground has to a certain extent also a bad effect upon the development of young ovule itself. Beyond this extent the shell no more develops, but the seeds in it can accomplish their normal development.

From the practical point of view the terrestrial exposure offers no hindrance to the development of the seeds if they have grown to a certain degree under ground. For instance, it is very often seen that the pods cultivated in sandy soil if exposed to the light when the rain has swept away the soil at the base of plant, are not adversely affected in the case of tolerably grown-up pods though those which had just penetrated into the soil would be severely hurt.

To what extent is the development of the pods and the gynophores hampered by light, and what are the physiological causes for this which takes place apparently in proportion to the degree of development? A study of these questions is to be hoped for in the future. It is worthy of notice, however, that only the lower seeds grow while the upper ones do not develop at all, in the case of b in Table 41. Observing this result in detail, the fact that only 2 or 3 lower seeds were able to develop a little while the others remained stationary in the case of b is known, which may suggest that the pods in this stage may have or not have just attained the limit of growth above ground. In other words, it is not an error to say that, the lower seeds in the pods used in this time, i. e. those grown for 8 days or so after soil-penetration, attained this limit. The upper seed could not yet attain this limit because the lower in general grows earlier than the upper as has already been proved in the previous sections. (chapter V, section 3, 5.)

The time necessary to attain to this stage of growth, about 8 days after soil-penetration, corresponds to the initial time for the sudden division and growth of the embryo in the ovary as shown in section 4 of this chapter. With regard to the growth of the cotyledon corresponding to the dimensions of the pod, the author made the following macroscopic observations.

TABLE 42.

Showing development of the ovule corresponding to the dimension of the pod. (1932)

	Pod		Upper ovule		Lower ovule	
	length	width	length	width	length	width
	cm	cm	cm	cm	cm	cm
1	1.23	0.63	0.20	0.09	0.29	0.16
	1.13	0.71	0.24	0.15	0.31	0.21
	1.24	0.72	0.20	0.11	0.30	0.17
	1.24	0.65	0.21	0.11	0.32	0.18
	1.34	0.96	0.22	0.13	0.38	0.21
	1.33	0.72	0.18	0.12	0.22	0.19
	1.42	0.62	0.32	0.13	0.31	0.16
	1.51	0.72	0.18	0.12	0.22	0.19
	1.53	0.86	0.23	0.13	0.32	0.21
	1.57	0.75	0.23	0.17	0.33	0.19
2	1.41	0.86	0.25	0.13	0.38	0.22
	1.49	0.84	0.23	0.13	0.40	0.22
	1.51	0.93	0.36	0.17	0.42	0.29
	1.62	0.93	0.34	0.19	0.42	0.23
	1.68	0.83	0.32	0.17	0.43	0.24
	1.71	0.86	0.37	0.19	0.48	0.28
	1.76	0.89	0.26	0.13	0.26	0.21
	1.77	0.91	0.23	0.14	0.43	0.22
	1.79	1.01	0.38	0.18	0.42	0.25
	1.80	0.98	0.33	0.17	0.47	0.24
3	1.97	1.18	0.66	0.27	0.53	0.34
	2.03	1.00	0.43	0.20	0.49	0.22
	2.13	1.24	0.42	0.20	0.48	0.32
	2.37	1.27	0.50	0.30	0.57	0 48
	2.05	1.03	0.43	0.22	0.51	0.23

1. Those showing no sign of embryo.
2. Those developing embryo only in lower seed.
3. Those developing embryo in both upper and lower seed.

According to the results of this experiment, no cotyledon grows on the upper and lower ovule when the pod reaches about 1.10-1.50 cm. in length. The poor development of the pods and seeds caused by their terrestrial exposure shown in the above experiment (Table 41), may be considered to correspond to this stage. In a pod of 1·50–1.80 cm. in length, only the embryo of the lower seed is able to grow. The only two or three lower seeds having grown in the case of b (Table 41) seem to belong to this stage of pods. But when the pod develops over 1.90 cm., cotyledons will grow in the upper as well as in the lower seed, in which case the seeds will continue to develop even though they are exposed to the light above ground.

9. Summary

The experiments made can be summarized as follows:

(1) The ovule before fertilization grows gradually as it approaches the moment of flowering. The upper ovule is longer, but narrower than the lower.

(2) After fertilization the ovule gradually grows even above ground, but not beyond a certain limit. The lower one has grown longer and wider by this time than the upper.

(3) The beginning of the subterranean fructification is, as already shown in the former chapter, controlled by the outer and inner conditions affecting the gynophore and its plant. Under the common open field condition it begins to fructify on the 5th or 6th day after soil-penetration. The ovule grows remarkably during its soil-penetration even before fructification, the lower seed being obviously larger than the upper.

(4) The gynophore ceases to elongate as soon as it begins to fructify, and the ovary as well as the ovule suddenly swell.

(5) The embryo in the ovule is entirely dormant while above ground, and it continues to be dormant even under the soil, because it suddenly begins to divide itself and develop only three or four days after the beginning of fructification.

(6) After the beginning of fructification the lower ovule begins, first of all, to develop and swell, followed successively by the upper ones.

(7) The dimensions of the matured pod, and of the upper and the lower seed are controlled by inner and external conditions, such as variety, method and time of cultivation, soil condition and so on. The upper seed is bigger than the lower generally in varieties belonging to the runner type, but in the three-seeded variety belonging to the bunch type, the middle one is the smallest because it has been compressed by the other two.

(8) The pod which has penetrated into sandy soil grows larger than in the clayish soil.

(9) With the two-seeded variety belonging to the bunch type, two experiments were made. In the first the upper seed was shown

to be larger than the lower, but in the second occurred quite the contrary. The experiment made to alter the size of the upper seed and the lower artificially by altering the subterranean position of the pod produced quite satisfactory results.

(10) When the pods having begun growth after soil-penetration are exposed again above ground, the ovary having grown to a certain degree no longer swells the shell, but the ovule in it develops normally in spite of the influence of light and water. The limit of time necessary to allow or not the deyelopment of the ovule above ground seems to be by the third or forth day after the beginning of subterranean fructification.

(11) The total number of either matured fruit, non-matured fruit, subterranean gynophore or terrestrial gynophore, increases little by little keeping pace with the growth of the plant. The ratio of the gynophores in the stage of subterranean penetration to the total of promising gynophores becomes lower during the later period of growth, which may be caused by the lesser chance of terrestrial gynophores to penetrate into the soil. The ratio of the matured fruits to the total number or to the number of soil-penetrated ones becomes usually higher according to the growth of the plant.

VI. FLOWER- AND FRUIT-BEARING HABITS

MARCGRAF and PISO(17) were the first to figure the whole plant. Their figure is correct except that it shows no blossom and represents the nuts as developing on the lateral roots.

WALDRON(20), in his description of the types and varieties of peanuts, speaks of sterile and fertile flowers, while in the description of the bunch type he mentions fertile flowers grouped at the base of stem, and infers that sterile blossoms are to be found higher up on the stems and branches.

Beside him, the existence of sterile or staminate flowers is recognized by a few authors such as BAILEY(3) and ROBBINS.(18)

Earlier botanists, before 1805, all described the structure of the blossom erroneously. The stem-like calyx-tube was supposed to be a flower stalk. In 1805 POITEAU published the first correct description of the structure of the blossom. BROWN afterwards confirmed POITEAU's description in 1816. Notwithstanding the work of POITEAU, BENTHAM(1) as late as 1839 writes of Arachis as a plant with dimorphic flowers. He describes one form having calyx and corolla, which is always sterile, the fertile flowers having neither calyx, corolla nor stamens; but from two bracteolae, similar to those which are formed at the base of the sterile flowers, proceeds a stiff rigid stipe, which is speedily reflexed, elongated, and terminates in a short point. NEISLER in 1865 found that the flowers of the Arachis are all petal-bearing and fertile. What BENTHAM(1) mistook for a cleistogamous blossom was simply the elongated gynophore.

SPRECHER von BERNEGG(21) observed that the peanut begins to blossom at eight or nine in the morning, withers in the daytime and fades entirely the next morning. According to the description given by RICHTER(17), each plant has a flowering period of sixty-two days on the average during which 60.6 flowers will open, i. e. approximately one flower a day. Besides the chasmogamous flowers on the earth, according to PETTIT(15) and SPRECHER von BERNEGG(21), there are cleistogamous flowers under the ground, producing from the subterranean portion of the stems or branches, the buds of which are small and faded-yellow in color.

The author attempts in this chapter to consider as minutely as he can the habits of peanut plants especially in connection with flower- and fruit-bearing.

1. The number of flowers

The author tried to discover the number of flowers per plant in 1931 and in 1932.

The materials used in 1931 had been sown upon two different dates, on the 23rd of April and on the 23rd of May respectively, and the results in the two cases were compared. The variety selected was "*Java Shoryu No. 3*", ten plants of which were tested. The day on which the majority of them bloomed was regarded as the first day of flowering, and the day when the majority of them ceased to bloom was regarded as the last day of flowering, whereon the plants were withered already and quite beyond the period for being plucked from the standpoint of cultivation.

The dates are as follows:

	First day of flowering	Last day of flowering	Flowering period
Sown April, 23rd	May, 26th (34th day after sowing)	Aug. 21st	87 days
Sown May, 23rd	June, 22nd (31st day after sowing)	Sep. 22nd	93 days

In 1932 the author investigated the differences between "*Java Shoryu No. 3*" and "*Java Tairyu*", that is to say, between the bunch type and the runner type. Using ten plants of each variety for the experiment, the day upon which even one of them began to bloom was regarded as the first day of flowering, as shown below:

Java Shoryu No. 3	May, 10th
Java Tairyu	May, 12th

The investigation was brought to a close earlier than on the previous year, and it was found that the flowering period for the former is sixty nine days from first flowering and for the latter seventy four days, and those period may be not too early to consider as the harvesting time.

The average number of flowers per plant on each day during the experiments is given in the following table:

TABLE 43.

Showing number of flowers on each day during the flowering period. (1931, 1932)

Date after flowering	*Java Shoryu No. 3*						*Java Tairyu*	
	1931				1932		1932	
	Sown April, 23rd		Sown May, 23rd					
	Average number	Total per every 5 days	Average number	Total per every 5 days	Average number	Total per every 5 days	Average number	Total per every 5 days
1	0.5		1.3		0.2		0.1	
2	2.0		4.1		0.2		0.0	
3	0.7		4.5		0.4		0.5	
4	2.8		5.5		0.8		0.3	
5	3.0	9.0	4.2	19.6	1.6	3.2	1.0	1.9
6	2.2		3.5		1.2		1.3	
7	4.0		5.1		1.3		1.3	
8	3.3		3.6		3.0		1.6	
9	1.6		5.1		1.3		1.4	
10	2.8	13.9	6.5	23.8	3.6	10.4	1.6	7.2
11	3.7		7.1		3.9		3.1	
12	3.2		7.4		4.7		2.2	
13	4.9		7.1		4.1		4.6	
14	6.1		8.9		5.7		3.0	
15	6.9	24.8	8.3	38.8	6.0	24.4	4.7	17.6
16	3.6		7.7		6.0		2.1	
17	4.7		8.0		5.6		2.5	
18	7.3		8.1		4.2		4.0	
19	5.4		8.8		3.2		7.1	
20	8.5	29.5	8.0	40.6	6.5	25.5	4.9	20.6
21	9.7		8.7		9.3		3.0	
22	9.4		8.6		4.6		5.9	
23	5.6		9.0		1.8		4.7	
24	11.7		10.0		8,5		6.5	
25	5.7	42.1	9.7	46.0	5.5	29.7	9.6	29.7
26	9.0		7.3		6.1		4.3	
27	1.6		9.4		7.5		9.6	
28	7.7		13.2		4.7		7.6	
29	10.0		10.8		8.5		3.3	
30	9.8	38.1	10.9	51.6	4.9	31.7	2.8	27.6
31	8.1		10.1		2.3		7.9	
32	10.5		14.4		2.6		7.9	
33	8.3		13.0		5.1		7.6	
34	8.0		12.3		4.1		9.8	
35	7.6	42.5	11.5	61.3	4.8	18.9	9.7	42.9
36	12.2		10.7		7.1		9.9	
37	13.6		13.8		5.4		11.2	
38	12.8		12.0		4.0		19.3	
39	12.1		13.7		6.2		15.4	
40	13.6	64.3	14.6	64.8	5.3	28.0	13.8	69.6
41	15.1		11.6		2.5		14.1	
42	15.9		10.6		4.2		15.3	
43	12.1		10.4		4.7		19.3	
44	13.3		10.9		3.8		19.4	
45	14.8	27.1	11.4	54.9	3.3	18.5	19.2	87.3

Date after flowering	*Java Shoryu No. 3*						*Java Tairyu*	
	1931				1932		1932	
	Sown April, 23rd		Sown May, 23rd					
	Average number	Total per every 5 days	Average number	Total per every 5 days	Average number	Total per every 5 days	Average number	Total per every 5 days
46	14.4		13.6		3.5		18.5	
47	13.6		15.9		3.2		17.3	
48	8.5		15.3		3.0		18.4	
49	12.1		16.4		2.3		18.5	
50	11.8	60.4	12.4	73.6	4.3	16.3	18.5	91.2
51	12.7		18.0		2.9		20.7	
52	10.9		8.0		4.6		26.0	
53	7.7		15.7		6.4		20.9	
54	5.9		13.4		5.0		19.2	
55	8.0	45.2	14.0	69.1	6.6	25.5	16.9	103.7
56	8.0		15.5		5.3		27.2	
57	8.8		15.2		4.8		17.4	
58	6.7		16.0		5.9		22.2	
59	6.1		9.3		3.7		33.5	
60	4.6	34.2	11.2	67.2	6.1	25.8	32.5	132.8
61	4.0		7.3		9.8		39.4	
62	4.8		9.4		11.3		30.7	
63	5.7		6.3		12.2		29.1	
64	5.3		4.8		6.4		39.3	
65	4.4	24.2	5.2	33.0	3.4	43.1	29.7	168.2
66	4.4		3.9		7.6		31.9	
67	3.3		1.6		2.4		28.7	
68	3.0		1.6		6.2		28.5	
69	2.2		1.6		6.0		32.2	
70	2.0	14.9	3.0	11.7	—		28.5	149.8
71	0.9		6.5		—		28.1	
72	0.9		4.7		—		31.2	
73	1.2		4.6		—		23.1	
74	2.4		2.3		—		21.2	
75	1.0	6.4	2.6	20.7	—		—	
76	1.9		2.5		—		—	
77	2.0		1.4		—		—	
78	3.3		2.0		—		—	
79	1.1		1.2		—		—	
80	1.0	9.3	1.7	8.8	—		—	
81	0.9		2.9		—		—	
82	1.7		2.8		—		—	
83	1.1		2.0		—		—	
84	1.2		1.7		—		—	
85	0.6	5.5	3.9	13.3	—		—	
86	0.8		2.3		—		—	
87	1.2		1.4		—		—	
88	—		2.5		—		—	
89	—		2.2		—		—	
90	—		2.4	10.8	—		—	
91	—		1.3		—		—	
92	—		1.2		—		—	
93	—		1.7		—		—	
Total	537.5		713.8		323.2		1053.7	

The results derived from the experiment of 1931 show the number of flowers of bunch type ns follows:

TABLE 44.

Showing number of flowers of bunch type summarized from the results of the 1931 experiment.

	Total	Average per day
Sown April, 23rd	537.5	6.2
Sown May, 23rd	713.8	7.7

That is to say, those sown in May have many more flowers and show accordingly a larger average per day.

As far as the results of the experiment conducted in 1932 are concerned, though it ceased before the end of the flowering period, the bunch variety showed a total of as many as 323.2 flowers and an average of blossoms 4.68 per day. The total number for the flowers of each plant is as follows:

TABLE 45.

Showing total number of flowers on each plant of bunch type. (1932)

No. of plants	1	2	3	4	5	6	7	8	9	10
Number of flowers	240	223	316	375	422	285	244	345	260	522

In order to compare the results of the 1932 experiment with those obtained in 1931, the author had to consider the 1931 experiment as having been brought to a close on the 69th day, and thus obtained the following results:

TABLE 46.

Showing number of flowers derived from Table 44 which were obtained by interruption of the flowering period. (1931)

	Total	Average per day
Sown April, 23rd	512.3	7.4
Sown May, 23rd	653.0	9.5

As shown above the 1931 experiment showed a much greater number of blossoms.

The runner variety had as many as 1053.7 blossoms in all and on average per day of 14.24 flowers. The total of flowers opened from each plant is as follows:

TABLE 47.

Showing total number of flowers on each plant of runner type. (1932)

No. of plants	1	2	3	4	5	6	7	8	9	10
Number of flowers	1699	1271	946	1145	794	793	1129	807	1122	831

It must be concluded, therefore, that the flowers of the runner variety are much more abundant than those of the bunch variety.

Observing further the total number of flowers per every five days given in Table 43, the number of flowers of the bunch type reached a maximum between the 45th and the 50th day in the case of plants sown in April, and between the 50th and the 60th day in the case of those sown in May, as far as the 1931 experiment is concerned. The experiments conducted in 1932, having ceased before the finishing period of growth, it only revealed the gradual increase of the number of blossoms in the later days, especially in the case of the runner type, but it may be guessed that the number will decrease according as the end of the period of growth approaches.

The results mentioned above can be summarized as follows:

(1) The peanut blossoms incessantly during the whole period of growth. The prime period of flowering seems to be between the 45-50th day and the 66-65th day in the bunch type.

(2) There is a difference in the total number of flowers and in the average number per day between the bunch and the runner type. The latter blooms much more.

(3) The number of flowers varies greatly from year to year and according to the time of sowing. In point of fact it is variable, though according to RICHTER(17) each plant produces daily one flower.

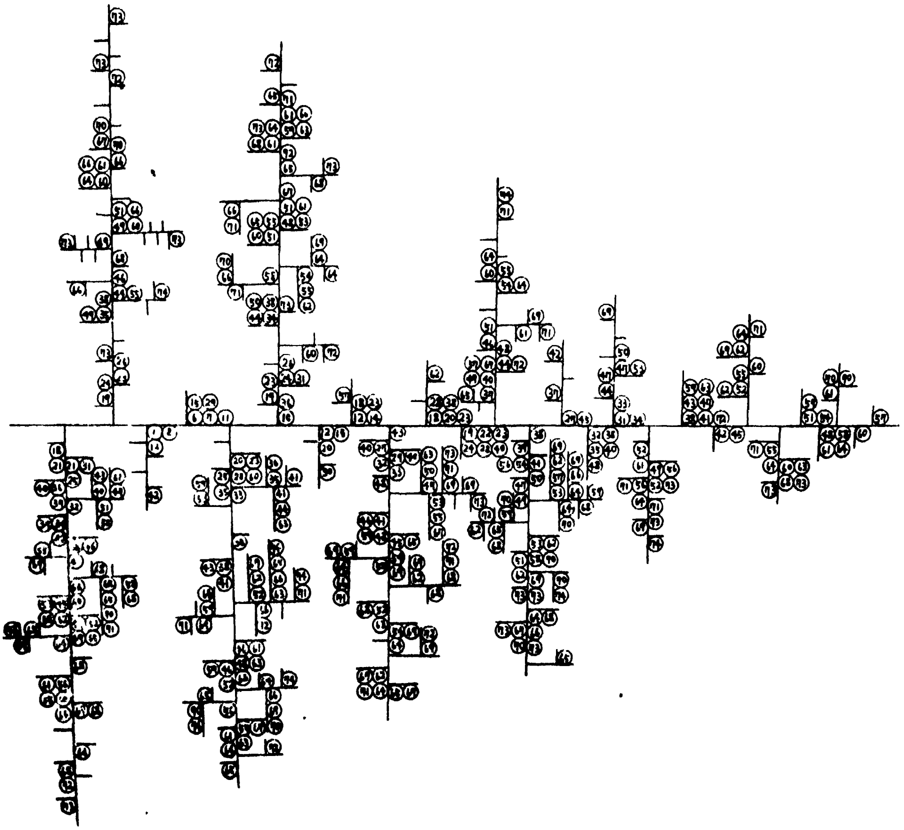
2. Order of flowering

The runner type differs characteristically in the way it spreads its branches and bears fruit from the bunch type. As far as the author's observations are concerned, in the bunch type as many as ten branches grow from the lower part of the main stem to the upper successively, from the axil of each of which flowers spring out. On the contrary, as the main stem of the runner type does not grow much, it spreads several elongated decumbent branches, from which secondary branches derive, numerous flowers issuing for the first time from each axil of the new branches.

Fifteen plants of each variety were used for the experiment in 1932 in order to decide the order of flowering. For the examples,

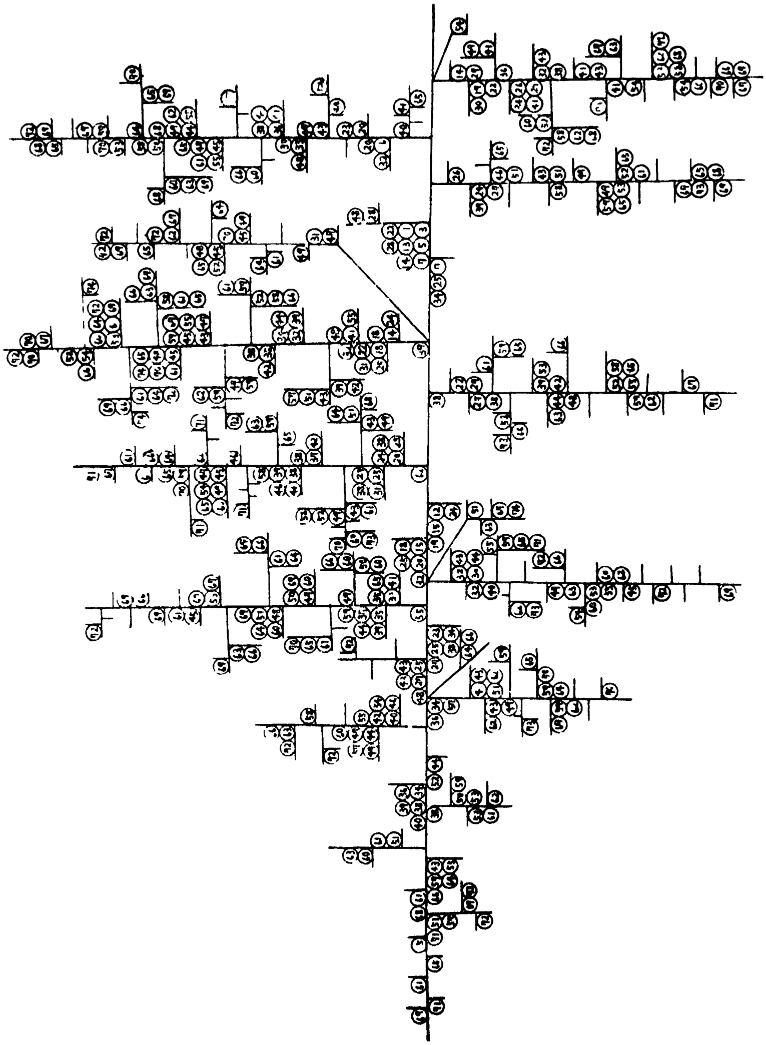
Text-fig. I. Showing the order of flowering

(a) 1st branch of runner type



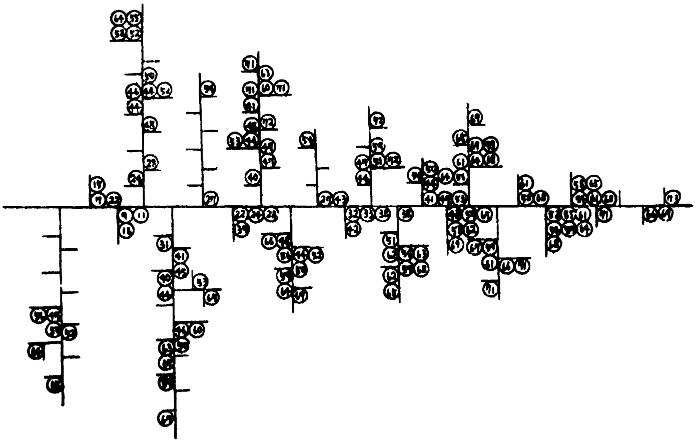
No. 8 of runner and No. 8 of bunch type are shown in Text-fig. I. (a) (b) (c) (d) and in Text-fig. I. (e) respectively. The number given in the figures shows the order of flowering, considering the day when one of them bloomed for the first time as 1, and so on.

(b) 2nd branch of runner type

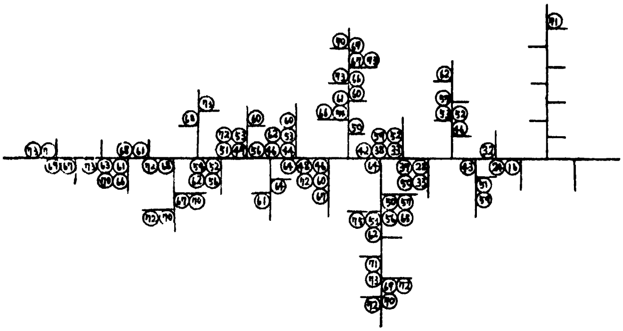


The first blossoms of the bunch type are generally seen to spring out from the bases of the basal branches, such as Branch 1, or 2, but there are exceptions such as blossoms springing simultaneously from the bases of Branch 1, 2. 3, and 4, and rarely such as no flower

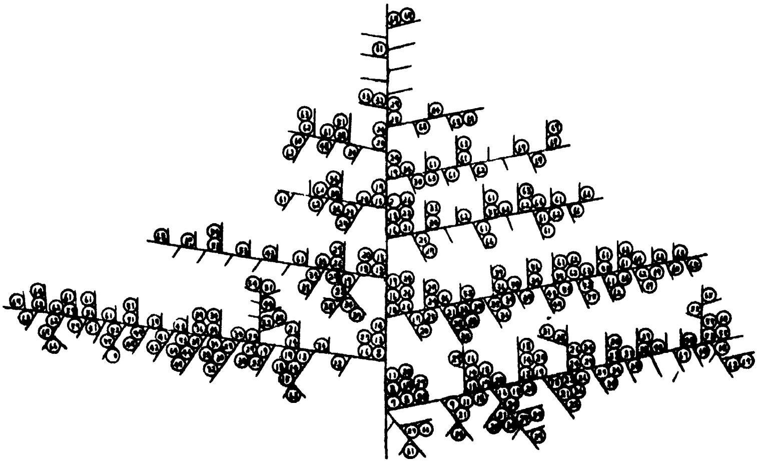
(c) 3rd branch of runner type



(d) 4th branch of runner type



(e) Bunch type



opening at the bases of those branches. Generally speaking, the bunch type put out the first bloom at the base of the basal branch progressing gradually towards the upper branches and again extending from the base of the respective branches to their tips.

In the case of the runner type, two basal branches developed first, seem to be in an opposite position and it is not easy to discern which of them develops first. Of course the first flowers will come out from these branches. Secondary branches will spring out from these two, the branching places on each branch are, for the sake of convenience called, starting from the basal one, node 1, 2, 3, etc.. The following table shows the No. of nodes which bear the first flower, in fifteen plants of the runner type.

TABLE 48.

Showing No. of nodes bearing the first flower in runner type. (1932)

		No. of plants														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No. of node bearing the first flower	1st branch	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4
	2nd branch	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4

As shown in the table mentioned above, only one of the fifteen plants in each case did not bloom at the fourth node, in other words, this proves clearly that flowers spring out generally at the fourth node. The basal nodes 1, 2 and 3 do not bear flowers, but do for the first time at the nodes of secondary branches which spring out later from them. Generally the bunch type blooms abundantly at the bases of its branches, but never so in the runner type, not even at the bases of the secondary branches having spread from the main branches. This characteristic however is only seen in the two lower main branches, but not in the branches of the upper part. They bloom in general from the first node and never at the base of the branch.

It may be said that the general habit of flowering of runner type is as follows:

1. The flowers tend to bloom progressively from the bases towards the tips of the lower two main branches at the nodes from which the secondary branches do not spread out.
2. Soon later the flowering takes place on the secondary branches tracing just the same process as the main ones. The nearer the secondary branches to the basal part of the main ones the earlier the flower-bearing.
3. Soon after the first flowering of the lower two main branches it progresses to the upper ones, and its process is similar to that, of the lower branches as mentioned above.
4. The first flower for the whole plant springs out at the fourth or rarely at the third nodes of the lower two main branches.

According to the observations made in the field, the flowering habits of the bunch as well as the runner type are much the same as mentioned above in other varieties of peanut.

3. Distribution of the flowers on the branches

The author observed the distribution of the flowers on the branches in the course of the experiment conducted in 1932, using five plants of the runner type and ten plants of the bunch type for the purpose. They were selected from the samples used in section 2. As the blossoms on the branches above the lower four ones are less in number, the author counted all of them on bloc. The results are shown in the following table: (See Table 49, p. 87.)

The table shows that most flowers of the runner type gather at the lower four branches, and that in the bunch type also the same thing occurs though a few flowers are distributed in the smaller branches besides these four main ones.

It can be said, therefore, that the flowers of the two varieties are commonly distributed on the 1st, 2nd, 3rd and 4th branches from the base of the plant. The entire results proves that the branches of the lower part are very effective for flowering, and especially the runner type distributes majority of its flowers on the two branches of the lower part and only a few on those above these two.

TABLE 49.

Showing distribution of the flowers on the branches. (1932)

	No. of plant	1st branch	2nd branch	3rd branch	4th branch	Other branches	Total
Runner type	3	346	310	203	68	19	946
	8	412	462	134	88	33	1129
	11	257	310	103	128	9	807
	13	493	378	134	86	31	1122
	15	269	230	145	167	20	831
	Average	355.4	338.0	143.8	107.4	22.4	967
Bunch type	2	57	55	38	45	45	240
	3	82	59	29	21	32	223
	5	103	75	43	47	48	316
	6	98	104	68	78	27	375
	7	122	102	77	65	56	422
	8	72	66	53	22	72	285
	11	60	43	72	37	32	244
	12	93	74	52	55	71	345
	13	62	58	50	19	71	260
	15	155	117	73	80	97	522
	Average	90.4	75.3	55.5	46.9	55.1	323.2

The author next observed the distribution of flowers on the node of every branch which is clearly shown in Table 50 using as examples the first branch of No. 8 of runner type No. 8 of bunch type, shown in Text-fig. I. (a) and Text-fig. I. (e) and also in table 49. The number of flowers on the exceptionally small branch sprung out from the base of the first branch of the latter type shown in the Text-fig. I. (e), is however excluded in this table, although it was added in the previous investigation (Table 49).

The bunch type (refer to Text-fig. I. (e)) distributes more flowers

TABLE 50.
Showing distribution of the flowers on the node of first branch of bunch and runner type. (1932)

No of nodes	1st branch	
	Bunch type	Runner type
Base	8	0
1	5	56
2	7	32
3	10	4
4	5	5
5	6	58
6	6	50
7	3	4
8	3	5
9	1	53
10	3	6
11	0	6
12	0	21
13	1	44
14	1	4
15	1	5
16	6	9
17	3	13
18	—	7
19	—	2
20	—	8
21	—	8
22	—	3
23	—	4
24	—	3
25	—	1
26	—	1
Total	69	412

at the node nearer the base of branch and less according as it advances towards the tip.

The difference in the number of flowers between the nodes is not very remarkable, although there is some irregularity which will more or less disappear on account of the subsequent flowering at the tip as it develops on.

The case of the runner type (refer to Text-fig. I. (a) (b) (c) (d)), however, is quite the reverse, because the number of flowers at the different nodes greatly varies. There are two kinds of nodes appearing alternately every two or three nodes, one of which does not spread the secondary branches while the other does. The former kind of nodes put out flowers only at the base and accordingly have but a few flowers. The author calls such a node blooming at the base reproductive node, and the node spreading secondary branches from which many flowers will sprung out vegetative node. However, even at the base of the vegetative node exceptionally one or two flowers often come out. As the reproductive and vegetative nodes will appear alternately every two or three nodes as mentioned above, the distribution of flowers becomes very irregular.

The number of reproductive nodes and vegetative ones as observed in five plants of the runner type during 68 days of flowering, excluding the branches above the lower four, is shown in the following table.

TABLE 51.
Showing distribution of vegetative and reproductive nodes on the branches. (1932)

No. of plant	Number of vegetative nodes					Number of reproductive nodes				
	1st branch	2nd branch	3rd branch	4th branch	Total	1st branch	2nd branch	3rd branch	4th branch	Total
3	15	10	8	10	43	12	15	15	9	51
8	13	13	9	6	41	13	13	12	12	50
11	13	14	9	11	47	12	11	7	10	47
13	12	13	8	6	39	14	14	12	14	54
15	15	12	7	10	44	13	14	15	13	55
Average	13.6	12.4	8.2	8.6	42.8	12.8	13.4	12.2	11.6	50.0

As shown in this table the total for the reproductive nodes is much larger. On the first branch the vegetative nodes are more than the reproductive ones, showing a ratio of 13.6 to 12.8, while above the second branch, the reverse is the case. It can be said, therefore, that there are more vegetative nodes grown on the lower part and more reproductive nodes on the upper part.

4. Proportion of the effective flowers

The flowers produced are not all effective as only a part of them can develop into gynophores, out of which, once more, only a few are able to penetrate into the soil. Therefore it is an interesting problem to investigate (1) what proportion out of total flowers can produce gynophores, (2) what percentage of these is able to penetrate into the soil and fructify, and finally (3) how many of the fruitful gynophores can attain to maturity.

Experiment 1.

The effective flowers increase incessantly according as the plant develops. The flowers produced in the earlier stage develop gradually into the matured fruits, and the flowers coming out later, are transformed into gynophores and penetrate into the soil one by one; thus it can be said that the effective flowers on the plant are incessantly transforming themselves. In other words considering the process as a cycle, we shall find at any moment, specimens of effective flowers in a continuous process of transformation, from flower to fruit.

Concerning the numerical increase of fruit in accordance with the growth of plant, the author had already referred to in the experiment conducted in 1931 (Table 38). In order to observe the transformation of the effective flowers as the plant develops, the author tried to find the ratio between the number of fruits in various stages shown in the table 38 and the number of flowers which already had been the subject of investigation in section 1 of this chapter (Table 43). As the plants compared in this experiment are quite different from one another, the proportion is accordingly not so accurate, but it may be useful as reference data.

As had been seen in the previous experiment (Table 15) the flower needs a six days period after fecundation before it develops into a gynophore. Consequently the total number of flowers on the day of experiment minus the number of flowers having come out during the preceding six days is to be regarted as the number of flowers to be for compared.

The results are shown in the following table:

TABLE 52.

Showing proportion of the effective flowers in various stages in every week after sowing. (1932)

	Weeks after sowing								
	9	10	11	12	13	14	15	16	17
Number of flower	128.3	176.0	250.6	349.8	427.1	475.2	507.1	519.7	530.9
Matured fruit	—	—	4.6	15.4	22.0	30.4	39.2	46.2	51.2
%	—	—	1.8	4.4	5.2	6.4	7.7	8.9	9.6
Non-matured fruit	10.4	18.2	16.4	22.2	27.4	25.2	32.2	30.0	33.6
%	8.1	10.3	6.5	6.3	6.4	5.3	6.3	5.8	6.3

	Weeks after sowing								
	9	10	11	12	13	14	15	16	17
Subterranean gynophore	30.0	39.8	35.6	36.8	33.4	48.4	62.2	48.8	46.6
%	23.4	22.6	14.2	10.5	7.8	10.2	12.3	9.4	8.8
Terrestrial gynophore	21.8	29.6	32.2	42.4	54.8	66.4	112.8	119.2	133.0
%	17.0	16.8	12.9	12.1	12.8	14.0	22.2	22.9	25.1
Total subterranean fruit	40.4	58.0	56.6	74.4	82.8	104.0	133.6	125.0	131.4
%	31.5	33.0	22.6	21.3	19.4	21.9	26.3	24.1	24.1
Total	62.2	87.6	88.8	116.8	137.6	170.4	246.4	244.2	264.4
%	48.5	49.7	35.4	33.3	32.2	35.9	48.5	47.0	49.8

The results of the experiment aiming at investigating the transformation of effective flowers in accordance with the development of the plant are as follows:

(1) Rate for the matured fruits gradually increases, reaching about 10% in the course of seventeen weeds.

(2) Rate for the non-mutured fruit remains unchangcd, keeping always between 5% and 10%.

(3) Rate for the subterranean gynophores progressively decreases.

(4) Rate for the terrestrial gynophores is inclined to increase.

(5) Rate for the effective gynophores penetrating into the soil is inclined to decrease a little.

(6) The rate for the whole effective gynophores is almost unvaried, keeping between 40% and 50%. The rate for the terrestrial gynophores is much the same as that for the whole of the subterranean fruits and gynophores after the 17th week.

Experiment 2.

Using ten plants of each variety, (runner and bunch type) which has been used previously for investigating the number of flowers, and taking the plants of the runner type out of the soil on 24th of July 1932 and those of the bunch type on the 17th of July 1932, the author observed the ratio of effective flowers borne by the plants. As shown in the previous experiment the figure required is given by the total number of flowers produced less those produced in the previous six days.

The results are shown in Table 53 and Table 54.

TABLE 53.

Showing number of the effective flowers borne by a plant in various stages of development. (1932)

	No. of plants	Number of flower	Matured fruit	Non-matured fruit	Subterranean gynophore	Terrestrial gynophore	Total subterranean fruit	Effective gynophore
Java Shoryu No. 3	2	202	36	11	34	52	81	133
	3	189	59	6	20	58	85	143
	5	285	48	17	24	125	89	214
	6	335	53	20	28	137	101	238
	7	385	65	26	63	95	154	249
	8	257	45	19	27	74	91	165
	11	222	34	17	26	66	77	143
	12	316	46	20	20	109	86	195
	13	229	44	14	21	70	79	149
	15	492	45	39	69	195	153	348
	Average	291.2	47.5	18.9	33.2	98.1	99.6	197.7
Java Tairyu	1	1453	36	44	68	995	148	1143
	2	1108	31	31	63	842	125	967
	3	816	61	26	28	489	115	604
	4	930	40	39	82	506	161	667
	5	689	59	24	37	428	120	548
	6	651	48	11	27	442	86	528
	8	929	42	58	22	497	122	619
	11	685	55	25	24	394	104	498
	13	902	20	56	35	524	111	635
	15	731	44	33	33	385	110	495
	Average	889.4	43.6	34.7	41.9	550.2	120.2	670.4

TABLE 54.

Showing proportion of the effective flowers borne by a plant in various stages of development. (1932)

		Java Shoryu No. 3	*Java Tairyu*
Rate for number of flower	Matured fruit	% 16.3	% 4.9
	Non-matured fruit	6.5	3.9
	Subterranean gynophore	11.4	4.7
	Terrestrial gynophore	33.7	61.9
	Total subterranean fruit	34.2	13.5
	Effective gynophore	67.9	75.4
Rate for numbor of gynophore	Matured fruit	24.0	6.5
	Non-matured fruit	9.6	5.2
	Total subterranean fruit	16.8	6.2
	Total terrestrial gynohore	49.6	82.1
Ratio of matured fruit to total subterranean fruit		47.7	36.3

Summarizing the results as shown in the tables above we find:

1. The bunch type has about 70% of effective flowers, half of which are terrestrial gynophores and the rest subterranean. The matured fruits represent 16.3%.

   The runner type has about 75% of effective flowers, 60% of which are terrestrial gynophores but the proportion of gynophores penetrated into the soil is low. Moreover, the proportion of matured fruit is only 5%.
2. The absolute number of matured fruits does not differ very widely between the bunch and the runner type, remaining at about 45, whereas the runner type has a great number of terrestrial gynophores, subterranean gynophores and incomplete non-matured fruits. This relation varies apparently according to the period of picking. In this experiment the phenomenon is caused by the earlier unearthing of the plants. Therefore, the rate mentioned above will vary according to the conditions present during the growing stage of the plant.

As both the bunch type and the runner type have about 70% and 75% of effective flowers respectively, the remaining 25-30% are accordingly wasted on the plant. This phenomenon may be caused by the outer and internal conditions of plant such as to prevent the fertilization or development of gynophore with fertilized ovary. It is never due to the existence of sterile or staminate flowers as mentioned in the introduction of this chapter, becauee the flower of peanut is doubtlessly harmophrodite as far as the author's observation is concerned.

However the author found in his experiment the abnormal sterile flowers among them, the style of which is exceedingly shorter than the normal attaining merely to the middle part of the inner cavity of calyx-tube. They are of course perfectly incompatible for the pollination and might be mistaken as the staminate flowers. According to the author's investigation the rate of such abnormal flowers is only less than 3% for the total, approaching closely to the 25-30% of wasted flowers as mentioned above. Details concerning such flowers will be mentioned in the future report.

5. Distribution of the effective flowers on the branches

As stated above most flowers of the runner type as well as of the bunch type bloom on the four lower branches. The author has here tried to ascertain the distribution of the effective flowers on each branch. Using five plants of the runner type and ten of the bunch type, all of them being the same individuals mentioned in section 3, and dividing the effective flowers into four stages: matured fruit, non-matured fruit, subterranean gynophores and terrestrial gynophores, the author investigated the respective distribution of the effective flowers. The number of flowers is, of course, the total less those having come out during six days.

The average number for one plant is as follows, Table 55 showing the bunch type and Table 56 showing the runner type respectively:

TABLE 55.

Showing distribution of the effective flowers on the branches of bunch type. (1932)

	1st branch	2nd branch	3rd branch	4th branch	Other branches	Total
Number of flower	82.3	69.6	49.5	42.0	47.8	291.2
Ratio to total (%)	28.3	23.9	17.0	14.4	16.4	
Matured fruit	16.5	12.6	7.4	6.4	4.6	47.5
Ratio to total (%)	34.7	26.5	15.6	13.5	9.7	
Non-matured fruit	5.6	5.0	2.6	2.5	3.2	18.9
Ratio to total (%)	29.6	26.5	13.8	13.2	16.9	
Snbterranean gynophore	9.5	8.8	4.1	4.6	6.2	33.2
Ratio to total (%)	28.6	26.5	12.3	13.9	18.7	
Terrestrial gynophore	23.5	20.5	19.5	15.9	18.7	98.1
Ratio to total (%)	24.0	20.9	19.9	16.2	19.1	
Total subterranean fruit	31.6	26.4	14.1	13.5	14.0	99.6
Ratio to total (%)	31.7	26.5	14.2	13.6	14.1	
Effective gynophore	55.1	46.9	33.6	29.4	32.7	197.7
Ratio to total (%)	27.9	23.7	17.0	14.9	16.5	
Ratio to total for each branch (%)						
Matured fruit	20.0	18.1	14.9	15.2	9.6	16.3
Non-matured fruit	6.8	7.2	5.3	6.0	6.7	6.5
Subterranean gynophore	11.5	12.6	8.3	10.9	13.0	11.4
Terrestrial gynophore	28.6	29.5	39.4	37.9	39.1	33.7
Total subterranean fruit	38.3	37.9	28.5	32.1	29.3	34.2
Total effective gynophore	66.9	67·4	67.9	70.0	68.4	67.9

TABLE 56.

Showing distribution of the effective flowers on the branches of runner type. (1932)

	1st branch	2nd branch	3rd branch	4th branch	Other branches	Total
Number of flower	298.6	290.0	118.0	87.2	18.8	812.6
Matured fruit	16.4	16.8	7.2	4.0	0.0	44.4
Ratio to total (%)	36.9	37.8	16.2	9.0	0.0	
Non-matured fruit	14.2	16.0	6.0	3.2	0.2	39.6
Ratio to total (%)	35.9	40.4	15.2	8.1	0.5	
Subterranean gynophore	8.8	12.2	5.4	1.8	0.2	28.4
Ratio to total (%)	31.0	43.1	19.0	6.3	0.7	
Terrestrial gynophore	169.6	157.0	71.2	51.8	8.2	457.8
Ratio to total (%)	37.1	34.3	15.6	11.3	1.8	
Total subterranean fruit	39.4	45.0	18.6	9.0	0.4	112.4
Ratio to total (%)	35.1	40.0	16.5	8.0	0.4	
Effective gynophore	209.0	202.0	89.8	60.8	8.6	570.2
Ratio to total (%)	36.7	35.4	15.7	10.7	1.5	
Ratio to total for each branch (%)						
Matured fruit	5.5	5.8	6.1	4.6	0.0	5.5
Non-matured fruit	4.8	5.5	5.1	3.7	1.1	4.9
Subterranean gynpohore	2.9	4.2	4.6	2.0	1.1	3.5
Terrestrial gynpohore	56.8	54.1	60.3	59.4	43.6	56.3
Total subterranean fruit	13.2	15.5	15.8	10.3	2.1	13.8
Total effective gynophore	70.0	69.6	76.1	69.7	45.7	70.2

The following summary may be derived from the above tables:

(1) Distribution of the effective flowers of the bunch type keeps the following order: branch 1, 2, 3 and 4, the 1st and 2nd branches specially having a majority of blossoms and the 3rd and 4th much less. The total number of effective flowers grown on the

remaining branches is much the same as on branches 3 or 4. As far as the distribution of the four stages on each branch is concerned, though the rate for the non-matured fruits and the subterranean gynophores is not very different among the four branches, the matured fruits are seen more on the lower branches, while on the contrary, the terrestrial gynophores more frequent on the upper branches. In spite of these differences, the rate of the total number of effective flowers within each branch keeps almost constant.

(2) The distribution of the four stages in the runner type shows higher figures for branches 1 and 2, much less for branches 3 and 4, and only a few for the remaining branches. There is no great difference among branch 1, 2, 3 and 4 in the proportion of the four stages on each branch, but it is lowest on the remaining branches.

It can be concluded, therefore, that not only the flowers but the effective flowers are distributed more widely on the lower branches of the bunch type and especially on those of the runner type, and accordingly the lower branches are doubtlessly more important for peanut culture.

6. **Position of the effective flowers**

Having ascertained the distribution of effective flowers on each branch as reported in the preceding section, the author now tried to discover the position of effective flowers on each node of every branch by means of the following experiment.

First of all, the results obtained for the bunch type are to be explained. The plants tested are five in number being those selected from the samples that have been dealt with in section 3 of this chapter. For the example, the result of observation relating No. 8 of bunch type which corresponds to the plant indicated in Text-fig. I. (e) is shown in Text-fig. II. (e) and Table 57. The number of flowers, of course, represents the total less those having blossomed in the course of six days.

TABLE 57.

Showing position of the effective flowers on each node of every bunch type. (1932)

No. of branch	No. of node	Number of flower	Matured fruit.	Non-matured fruit	Subterranean gynophore	Terrestrial gynophore
1	Base	8	2	4	0	0
	1	5	1	1	1	0
	2	7	1	2	4	0
	3	10	5	1	0	3
	4	5	2	0	1	0
	5	6	3	0	0	0
	6	6	2	0	1	0
	7	3	0	0	1	1
	8	3	0	0	0	2
	9	1	0	0	0	0
	10	3	0	0	0	1
	11	0	0	0	0	0
	12	0	0	0	0	0
	13	0	0	0	0	0
	14	1	0	0	0	0
	15	1	0	0	0	0
	16	5	0	0	0	4
	17	2	0	0	0	0
	Total	66	16	8	8	11
Extraordinary branch of No. 1	Base	0	0	0	0	0
	1	0	0	0	0	0
	2	2	0	0	0	0
	3	1	0	0	0	0
	Total	3	0	0	0	0
2	Base	5	1	2	1	0
	1	1	1	0	0	0
	2	1	0	0	1	0
	3	6	3	0	0	0
	4	2	2	0	0	0
	5	4	3	0	0	0
	6	7	0	0	3	4
	7	5	1	0	1	0
	8	4	0	0	0	2
	9	5	0	0	0	1
	10	1	0	0	0	1
	11	2	0	0	0	2
	12	1	0	0	0	1
	13	2	0	0	0	0
	14	2	0	0	0	1
	15	3	0	0	0	2

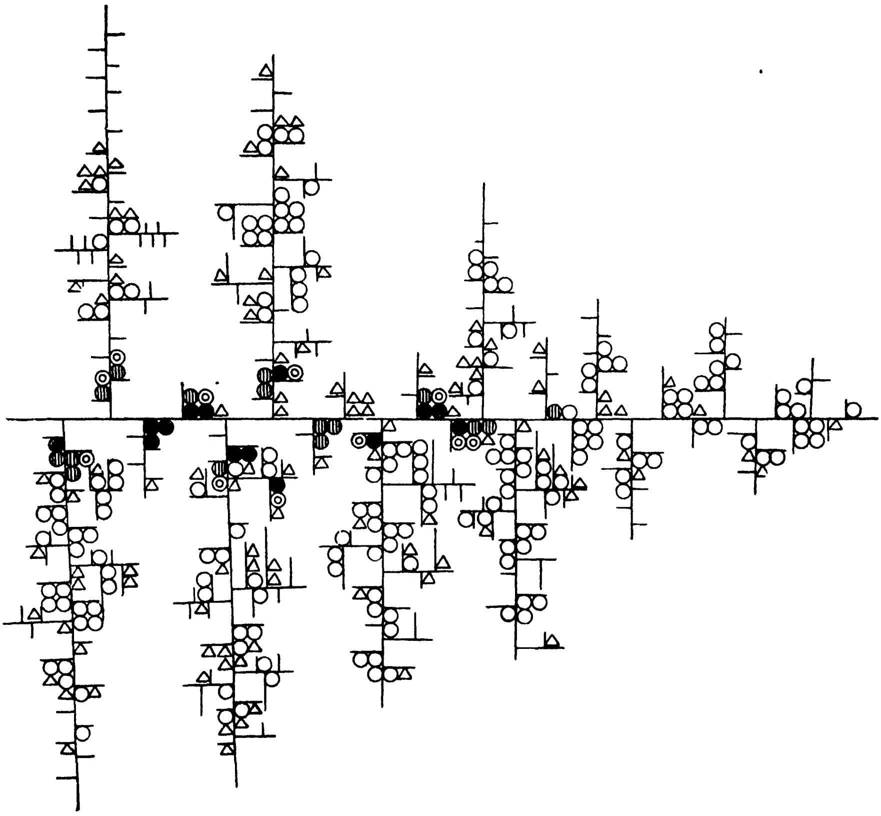
No. of branch	No. of node	Number of flower	Matured fruit	Non-matured fruit	Subterranean gynophore	Terrestrial gynophore
	16	1	0	0	0	0
	17	1	0	0	0	1
	18	2	0	0	0	2
	19	1	0	0	0	1
	20	3	0	0	0	2
	21	1	0	0	0	1
	22	2	0	0	0	0
	23	1	0	0	0	0
	Total	63	11	2	6	21
3	Base	6	2	2	0	0
	1	3	2	0	1	0
	2	3	2	0	0	0
	3	6	0	0	0	2
	4	1	0	1	0	0
	5	3	0	0	0	2
	6	3	0	0	0	2
	7	1	0	0	0	0
	8	2	0	0	0	1
	9	3	0	0	0	3
	10	5	0	0	0	2
	11	2	0	0	0	2
	12	2	0	0	0	2
	13	2	0	0	0	2
	14	2	0	0	0	2
	15	1	0	0	0	0
	16	1	0	0	0	1
	17	1	0	0	0	0
	18	1	0	0	0	0
	Total	48	6	3	1	21
4	Base	4	4	0	0	0
	1	6	2	0	1	0
	2	3	0	0	1	0
	3	2	0	1	1	0
	4	1	0	0	0	0
	5	0	0	0	0	0
	6	1	0	0	1	0
	7	0	0	0	0	0
	8	1	0	0	1	0
	9	0	0	0	0	0
	10	2	0	0	2	0
	Total	20	6	1	7	0

No. of branch	No. of node	Number of flower	Matured fruit	Non-matured fruit	Subterranean gynophore	Terrestrial gynophore
5	Base	6	2	3	0	0
	1	2	0	1	1	0
	2	2	0	0	2	0
	3	0	0	0	0	0
	4	0	0	0	0	0
	5	1	0	0	0	1
	6	3	0	0	0	2
	7	0	0	0	0	0
	8	2	0	0	0	0
	9	3	0	0	0	1
	10	1	0	0	0	0
	Total	20	2	4	3	4
6	Base	3	3	0	0	0
	1	3	0	0	0	2
	2	3	0	0	0	1
	3	1	0	0	0	1
	4	0	0	0	0	0
	5	1	0	0	0	1
	Total	11	3	0	0	5
7	Base	3	1	1	0	0
	1	2	0	0	0	1
	2	1	0	0	0	1
	3	1	0	0	0	0
	4	2	0	0	0	1
	5	1	0	0	0	1
	Total	10	1	1	0	4
8	Base	2	0	0	0	0
	1	1	0	0	1	0
	2	3	0	0	0	1
	3	1	0	0	0	1
	4	2	0	0	0	1
	5	2	0	0	0	2
	Total	11	0	0	1	5
9	Base	2	0	0	1	1
10	Base	2	0	0	0	1
14	Base	1	0	0	0	1
15	Base	0	0	0	0	0

Text-fig. II.

Showing position of the effective flowers on the branches

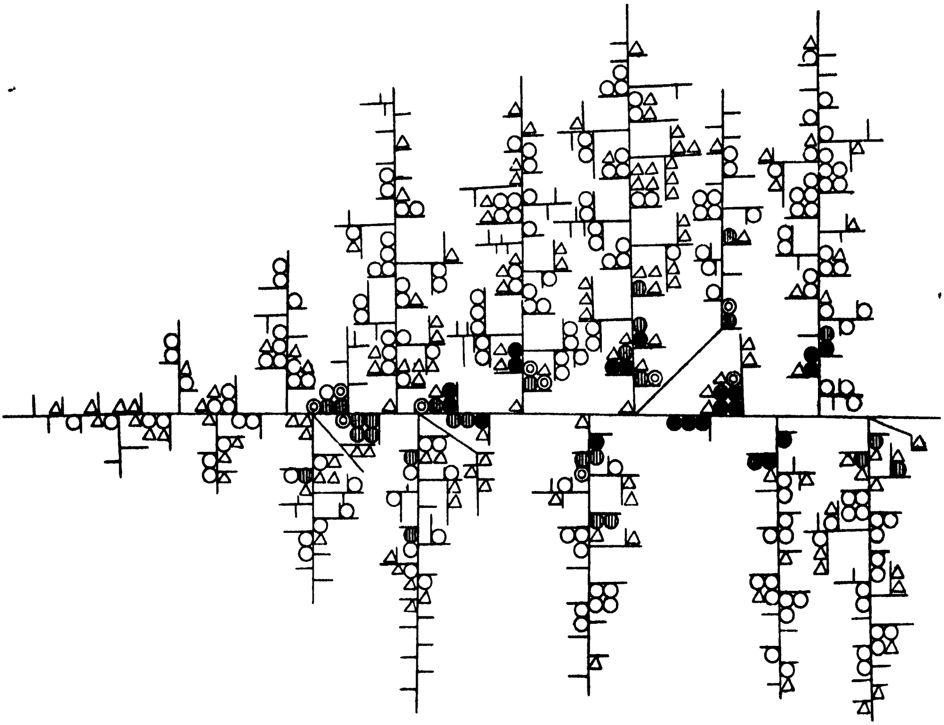
(a) 1st branch of runer type



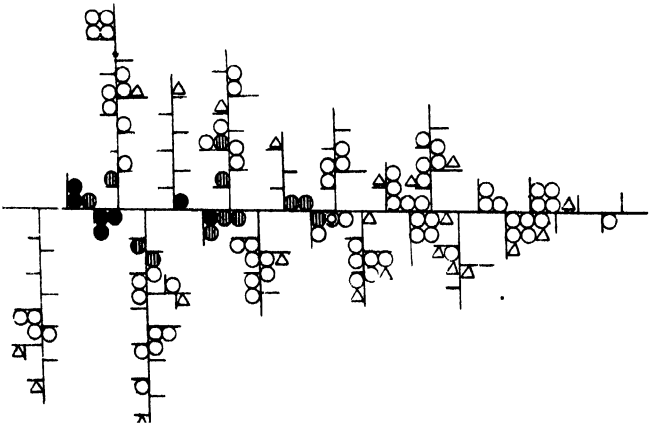
As clearly shown in the above table and Text-fig II. of the total effective flowers under soil-penetration (e. g. matured fruit, non-matured fruit and subterranean gynophores) the greater part are found on the nodes near to the base of each branch, especially on the lower branches and a few only at the bases of the upper branches.

In order to ascertain more clearly the fact mentioned above the distribution of effective nodes on each branch, from which the effective flowers for soil-penetration issue, was investigated with five plants used, the result of which is shown as follows: (see Table 58, p. 103).

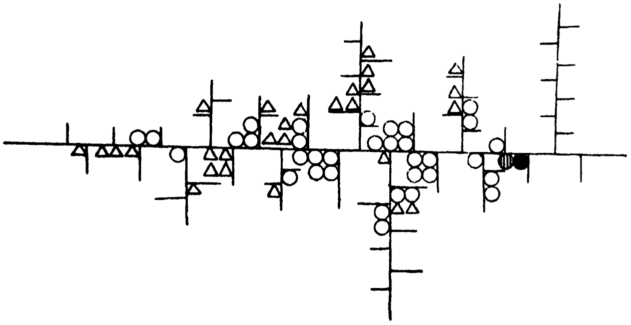
(b) 2nd branch of runner type



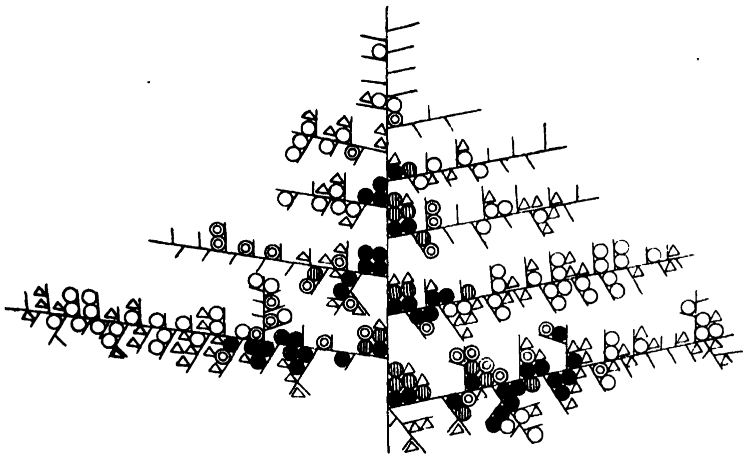
(c) 3rd branch of runner type



(d) 4th branch of runner type



(e) Bunch type



● Matured fruit ◍ Non-matured fruit ◎ Subterranean gynophore
○ Terrestrial gynophore △ Flower not advanced to gynophore

TABLE 58.

Showing distribution of the effective nodes on each branch of bunch type. (1932)

No. of plant	No. of branch	No. of node		
		Bearing matured fruit	Bearing non-matured fruit	Producing subterranean gynophore
5	1	6	12	9
	2	5	3	8
	3	4	1	6
	4	2	3	3
	5	B*	—	—
	6	B	—	B
	7	—	—	B
	8	B	—	B

No. of plant	No. of branch	No. of node		
		Bearing matured fruit	Bearing non-matured fruit	Producing subterranean gynophore
6	1	7	1	10
	2	6	11	9
	3	6	5	11
	4	5	7	8
	5	—	—	—
	6	B	B	—
	7	—	—	B
	8	B	B	—
	9	—	—	B
8	1	6	3	7
	2	7	B	7
	3	2	4	1
	4	1	3	3
	5	B	1	1
	6	B	—	—
	7	B	B	—
	8	—	—	B
	9	—	—	B
12	1	5	7	8
	2	6	7	8
	3	4	1	5
	4	5	4	—
	5	1	B	—
	6	B	—	—
	7	B	—	B
	8	B	—	—
	9	B	—	B
15	1	7	6	6
	2	5	13	14
	3	1	7	3
	4	3	6	6
	5	B	B	1
	6	B	—	B
	7	—	—	—
	8	B	B	—

* B means base of branch.

According to the above table, production of effective gynophores after soil-penetration is limited to the 10th branch; above the 6th they grow only on the bases of branch. The effective nodes in all branches do not exceed the 14th, and generally the 10th, while those being able to bear matured fruits are lower than the 7th.

As to the runner type, the same plants have been used as mentioned in section 3 of this chapter. Among them No. 8 which corresponds to Text-fig. I. (a) (b) (c) (d), is selected for example, the results being shown in Text-fig. II. (a) (b) (c) (d) and Table 59. The number of flowers indicates those on the day of unearthing from which were subtracted those having come out during the previous six days.

TABLE 59.

Showing position of the effective flowers on each node of every branch of runner type. (1932)

No. of branch	No. of node	Number of flower	Matured fruit	Non-matured fruit	Subterranean gynophore	Terrestrial gynophore
1	Base	0	0	0	0	0
	1	50	1	3	1	30
	2	23	0	2	2	8
	3	4	3	0	0	0
	4	5	2	1	1	0
	5	46	3	1	2	19
	6	39	1	2	1	21
	7	4	0	3	0	0
	8	5	0	0	0	0
	9	39	1	0	1	28
	10	6	2	1	1	0
	11	6	1	2	2	0
	12	15	0	0	0	9
	13	30	0	0	0	23
	14	4	0	1	0	1
	15	5	0	0	0	5
	16	8	0	0	0	5
	17	7	0	0	0	5
	18	6	0	0	0	4
	19	2	0	0	0	2
	20	6	0	0	0	6
	21	5	0	0	0	3
	22	3	0	0	0	3
	23	4	0	0	0	4
	24	1	0	0	0	1
	25	1	0	0	0	0
	26	1	0	0	0	1
	Total	325	14	16	11	178

No. of branch	No. of node	Number of flower	Matured fruit	Non-matured fruit	Subterranean gynophore	Terrestrial gynophore
2	Base	0	0	0	0	0
	1	35	0	3	0	18
	2	43	3	1	0	29
	3	21	2	1	0	13
	4	10	3	1	1	0
	5	3	3	0	0	0
	6	75	3	6	2	32
	7	24	1	4	1	11
	8	45	2	1	2	25
	9	4	1	2	0	0
	10	5	2	1	1	0
	11	23	0	2	0	9
	12	35	0	0	0	21
	13	5	0	4	1	0
	14	5	0	2	2	1
	15	18	0	1	0	7
	16	13	0	0	0	10
	17	2	0	0	0	2
	18	5	0	0	0	3
	19	7	0	0	0	3
	20	4	0	0	0	3
	21	5	0	0	0	2
	22	2	0	0	0	0
	23	2	0	0	0	1
	24	1	0	0	0	0
	25	1	0	0	0	1
	26	1	0	0	0	0
	Total	394	20	29	10	191
3	Base	0	0	0	0	0
	1	6	0	0	0	4
	2	3	2	1	0	0
	3	3	3	0	0	0
	4	12	0	1	0	10
	5	13	0	2	0	9
	6	2	1	0	0	0
	7	4	1	3	0	0
	8	9	0	2	0	6
	9	8	0	0	0	7
	10	3	0	2	0	0
	11	4	0	1	1	2
	12	4	0	0	0	4
	13	9	0	0	0	6
	14	6	0	0	0	5
	15	5	0	0	0	4
	16	7	0	0	0	5
	17	4	0	0	0	1
	18	3	0	0	0	3
	19	7	0	0	0	5
	20	5	0	0	0	4
	21	0	0	0	0	0
	22	0	0	0	0	0
	23	1	0	0	0	1
	24	0	0	0	0	0
	Total	118	7	12	1	76

No. of branch	No. of node	Number of flower	Matured fruit	Non-matured fruit	Subterranean gynophore	Terrestrial gynophore
4	Base	0	0	0	0	0
	1	0	0	0	0	0
	2	0	0	0	0	0
	3	2	1	1	0	0
	4	1	0	0	0	1
	5	3	0	0	0	3
	6	5	0	0	0	2
	7	4	0	0	0	4
	8	5	0	0	0	5
	9	7	0	0	0	4
	10	7	0	0	0	1
	11	5	0	0	0	5
	12	6	0	0	0	2
	13	2	0	0	0	1
	14	4	0	0	0	3
	15	4	0	0	0	0
	16	1	0	0	0	0
	17	2	0	0	0	1
	18	2	0	0	0	2
	19	3	0	0	0	0
	20	0	0	0	0	0
	21	1	0	0	0	0
	Total	64	1	1	0	34
Remaining	Total	28	0	0	0	18

Five plants used were also investigated as in the case of the bunch type for the confirmation of the effective nodes on each branch, the results of which are shown in the following table:

TABLE 60.

Showing distribution of the effective nodes on each branch of runner type. (1932)

No. of plant	No. of branch	No. of node		
		Bearing matured fruit	Bearing non-matured fruit	Producing subterranean gynophore
3	1st	6	13	8
	2nd	10	15	10
	3rd	4	4	2
	4th	0	4	3

No. of plant	No. of branch	No. of node		
		Bearing matured fruit	Bearing non-matured fruit	Producing subterranean gynophore
8	1st	11	14	11
	2nd	10	15	14
	3rd	7	11	11
	4th	3	3	—
11	1st	12	12	13
	2nd	8	8	9
	3rd	6	11	11
	4th	7	8	10
13	1st	13	13	12
	2nd	8	8	7
	3rd	7	10	8
	4th	2	—	—
	5th	—	—	6
	6th	—	1	—
15	1st	9	12	12
	2nd	11	14	11
	3rd	6	10	10
	4th	7	8	4

According to the above table, the blossoms effective for soil-penetration are rarely found above the fourth branch. The fertile nodes on each branch do not exceed the fifteenth, while matured fruits are grown up to the thirteenth node.

Further with regard to the runner type, there are two kinds of nodes, the vegetative and the reproductive node, which show the special characteristics in the production of effective flowers.

The following Table 61 shows how the effective flowers in various stages of development are distributed on the two kinds of nodes on branches 1–4; the results shown in the table are averaged up in Table 62.

The number of nodes bearing effective flowers for soil-penetration is superior among the reproductive. While the vegetative nodes are slightly superior in the respect of total number of effective flowers as compared with the reproductive, the reverse is true with regard to the number of matured fruits. From the standpoint of the number of blossoms produced, the vegetative node is absolutely superior to the

TABLE 61.

Showing distribution of the effective flowers in various stages of development on vegetative and reproductive node of runner type. (1932)

No. of Plant	No. of branch	Vegetative node				Reproductive node			
		Number of node	Matured fruit	Non-matured fruit	Subterranean gynophore	Number of node	Matured fruit	Non-matured fruit	Subterranean gynophore
3	1st	7	14	7	6	6	10	8	5
	2nd	4	9	4	3	5	11	3	6
	3rd	3	2	3	4	5	10	0	3
	4th	0	0	0	0	2	4	0	0
	Total	14	25	14	13	18	35	11	14
8	1st	5	6	8	7	6	8	8	4
	2nd	8	11	19	5	6	9	10	5
	3rd	3	0	5	0	6	7	7	1
	4th	0	0	0	0	1	1	1	0
	Total	16	17	32	12	19	25	26	10
11	1st	5	10	4	2	6	11	5	3
	2nd	5	11	4	5	3	7	3	1
	3rd	1	0	0	4	6	6	6	2
	4th	4	2	3	5	5	9	0	2
	Total	15	23	11	16	20	33	14	8
13	1st	5	4	9	5	6	4	11	3
	2nd	9	7	17	18	5	2	8	6
	3rd	1	0	0	1	3	3	3	1
	4th	0	0	0	0	5	0	8	1
	Total	15	11	26	24	19	9	30	11
15	1st	7	9	8	7	5	7	3	2
	2nd	6	7	7	9	6	10	5	3
	3rd	3	0	2	5	6	7	4	5
	4th	4	0	4	2	3	4	0	0
	Total	20	16	21	23	20	28	12	10

reproductive (see section 3), but, on the contrary, the rate of effective flowers is found to be much higher in the reproductive node. The vegetative node is inclined to grow flowers effective for soil-penetration near the base of the node.

TABLE 62.

Compendium of Table 61.

	Number of node	Matured fruit	Non-matured fruit	Subterranean gynophore	Total
Vegetative node	16.0	18.4	20.8	17.6	56.8
Reproductive node	19.2	26.0	18.6	10.6	55.2

One may, therefore, conclude that as far as the position of effective flowers borne is concerned, the number and proportion for those are, higher on the lower branch, and on the nodes near to the base of each lower branch, whether it be of the runner or of the bunch type. If one attempts to obtain good yields in peanut culture, this point should be taken into consideration as it is both interesting and important.

7. Summary

The, results obtained from these experiments may be thus summarized:

(1) Peanuts bloom incessantly during the whole period of growth from the commencement of the flowering stage.

(2) Although the number of flowers varies owing to the outer or inner conditions such as variety, time and method of culture, the runner type blooms much more profusely than the bunch type. The experiments showed that the bunch type produces seven to nine blossoms a day in 1931, and five flowers a day in 1932; and the runner type fourteen flowers a day in 1932 under ordinary field cultivation. According to the investigations conducted in 1931 the prime period of flowering for the bunch type is mostly between the 45-50th day up to 60-65th day.

(3) As far as the order of flowering is concerned the bunch type begins to bloom from the base of the lower branch spreading gradually up to its tip and then proceeding to the upper branches. The runner type, on the contrary, does not bloom at the base of decumbent branches but begins from the third or fourth node

of the lower branch proceeding gradually to the tip and extending little by little upwards to the higher decumbent branches and their secondary ones. It also does not bloom at the bases of the secondary branches, but begins from the lower nodes rising gradually to the upper ones.

(4) Flowers are mostly distributed on the four branches of the lower part of the runner type as well as of the bunch type. They are more thickly distributed on the lower branch, as is specially evident in the runner type.

Flowers distributed on the decumbent branches are seen much more on the node nearer to the base, in the bunch type, and less so on that nearer to the tip. But the runner type has on every two or three nodes a reproductive node without secondary branches and producing fewer flowers, and a vegetative node throwing out secondary branches and producing many blossoms. The vegetative nodes are distributed more on the lower branches and less on the upper branches.

(5) The proportion of flowers effective for the production of gynophores is over 70% in the bunch type and 75% in the runner type. The bunch type shows a higher rate of matured fruits which seems to fluctuate according to the maturity of the plant when it was unearthed.

(6) The effective flowers gather on the lower branches. As far as the effective gynophores able to penetrate into the soil are concerned, the bunch type has much more on the lower branches and only a few at the base of the upper branches. The runner type gathers the majority of its effective gynophores on its lower branches, while the reproductive nodes are superior to the vegetative node in their ratio of effective floweres to bearing flowers, and in the absolute number of matured fruits. The vegetative node grows effective gynophores at the basal portion of its secondary branches. The runner type grows, in general, effective flowers on the nodes further removed from the base.

VII. CONCLUSION

It is a well known fact that a gynophore does not bear fruit on the ground, but so far few biological investigations have been carried out in connection with this phenomenon, except those of PETTIT(15), VAN DER WOLK(25), WALDRON(26) and REED(16), as far as the author is aware.

The present author at first tried to ascertain as minutely as possible the requirements necessary for the occurrence of this phenomenon. According to the experiments made by VAN DER WOLK(25), with purpose to induce the artificial fructification above ground, all the efforts resulted perfectly negative not only when the gynophore was treated in the dark either under the dry or vapour-saturated condition, but also when either it was stimulated by various external pressure or inserted into dry soil, both being kept in the dark. On the contrary, positive results were obtained when the soil inserted was kept continually wet and when the gynophore was kept in soil-extract solutions obtained by boiling the soil. From these results, he concluded that the fructification is an activity produced by chemical matters found in the soil which nourishes the gynophore. WALDRON(26) reports that when either the gynophore is placed in a saturated atmosphere and not allowed to penetrate in any subtratum or allowed to grow in test-tube of tap water do not produce fruit. But it produces positive results either when allowed to grow in the dark test-tube of tap water, in sphagnum or in pure sand.

These results mentioned above are, however, merely the descriptions accompanying few critical and experimental data and throw no light whatsoever upon the other factors concerned.

In the present paper the author decided clearly that the light is harmful to the initial fructification, so that the exposure of gynophore to the ordinary white light even for a little while has an adverse effect, and no fructification takes place when exposed to it through all the day time. On the other hand, spectral rays of different wavelength are able to induce fructification even though this occurs very slowly and abnormally.

On the contrary, water is an indispensable factor for the initial fructification, which takes place only when the gynophore is directly in contact with water, while no fruit is born when it is grown in dry or even in vapour-saturated condition. This phenomenon is quite in accordance with the descriptions of Van der Wolk(25) and Waldron(26). It is, however, noteworthy that a nutrient in water is not only of no use for the beginning of fructification but even initially checks the development of fruit, which is contrary to Van der Wolk's views that the chemical matter of soil water acts only as a stimulating factor.

In addition to those factors mentioned above, oxygen is also indispensable. One of the reasons why the sandy soil is considered as good for peanut culture is that the gynophore is able to penetrate into it much easier than into clayish soil, moreover in view of the importance of the presence of oxygen for the beginning of fructification, sandy soil is also quite suitable for peanut culture, because it is porous and airy.

Thus the operations such as cultivation and moulding may be most suitable for the peanut culture, on the ground that they are conductive to the penetration of oxygen into the soil, and that they cause the gynophore above ground to penetrate more easily into the soil, so that the gynophore can meet the requirements necessary for the fructification.

It is consequently necessary for the gynophore to grow and elongate to a considerable extent above ground before penetrating down into the soil. So far as the elongation of the gynophore is concerned, it is decided that the presence of water, either aerial or subterranean, plays an important role in the process, thus the rainwater or high aerial humidity helps the ovule to develop when above ground, while in natural dry condition its development is hardly discernible. On the other hand, the presence of considerable moisture in the soil hastens the beginning of fructification after the penetration of gynophore into the soil.

From the facts mentioned above, it may be concluded that water is closely related to the growth and fructification of the gynophore. Thus, in the prime period of development of the gynophore, moderate amounts of rainfall are desirable, which not only help it to penetrate into the soil by softening the soil mechanically but also exert a good physiological effect upon the elongation of gynophores, the development of ovule above ground, and the beginning of fructification.

The length of gynophores above ground varies, from case to case, according to the time of their appearance. The author found the longer gynophore has a general tendency to begin to fructify earlier than the shorter, which means that the ovary of longer gynophores gains the chance more frequently to meet the element promoting fructification, i. e. aerial or subterranenan moisture. PETTIT(15) and WALDRON(26) have stated that the development of ovary above ground is stationary, while REED(16) reported that the fully elongated gynophore will make the tip of the ovary more or less corpulent. The author's experiment confirms the REED's opinion. It does, however, by no means alter the fact that the ovary shows no sign of fructification at all so long as it exists above ground.

The elongation of gynophores above ground is, of course, controlled by external or internal conditions. According to SPRECHER von BERNEGG's description, it elongates 2–4 mm. a day in the initial period of elongation, but 5–10 mm. a day afterwards. Contrary to this, the results secured in the author's experiment show in fact that it elongates more rapidly when it is still short but progressively slows down as it grows longer until it ceases at last to elongate.

The maximum length of the gynophore measured in this experiment is about 16 cm., which agrees approximately with the observations made by Pettit and Waldron. The elongation beyond this is very rarely found in the field. Many gynophores wither before they can reach this length.

The author ascertained further that the region in which the elongation takes place is just behind the ovary at the tip of the gynophore, agreeing with the results obtained by Pettit, Waldron and Reed who carried out similar experiments. The maximum elongation is found between 2 mm. and 4·5 mm. from the tip of ovary, and the nearer it is its base the less it elongates, and no elongation is found at the distance of about 7 mm. from the ovary.

Period necessary for the initial elongation of gynophore is 3 days after fertilization but the process is still obscure. It progresses rapidly and exactly on the 6th day. Geotropic curves begin simultaneously with the process.

The gynophores once having been in the soil are occasionally exposed above the ground owing to either artificial or natural causes such as rain, storm or cultivation. Among them, those before the beginning of fructification preserve the effect of the first penetration, i. e. they begin to fructify earlier than those of primary penetration, though the longer the period in the soil has lasted the shorter is the elongation and the shorter is the time required for fructification. Especially when a gynophore is subjected to rain or moisture during its terrestrial exposure it begins to bear fruit faster.

When ovaries having swelled to a certain extent after soil-penetration are exposed again above ground, the swelling of the shell no longer takes place but the ovules in it continue to grow in spite of the influence of light and water which are the requirements necessary for the beginning of initial fructification. WALDRON(26) was the only one who had more or less alluded to this problem but showing no numerical data. This phenomenon is in striking contrast to the behavior of gynophores before soil-penetration. The limit of time to allow this process seems to be by the 3rd or 4th day after the beginning of subterranean fructification. The shells and seeds thus exposed to the air able to develop larger in size when penetrated again into soil but the gynophores bearing them cease entirely to elongate. Besides, the subterranean gynophores exposed to the air for a second time before the beginning of fructification and terrestrial gynophores growing on higher branches of plant become quite slow in the elongation and lose very often the chance to fructify. Consequently it is important and indispensable that agriculturists should cultivate and mould the soil at the proper time in order to ensure the proper fructification of such gynophores as mentioned above.

The author traced further the history of the ovule from initial stage of development previous to fertilization up to that in which it attains to its full development. Firstly he succeeded in confirming the difference in the process of development due to the difference of the varieties.

The ovule begins to grow normally on the 5th or 6th day after soil-penetration, and those near the basal position grows in the first place, followed successively by the upper ones. Reed had made the embryological investigations of the peanut, but had not indicated at what time the embryo begins to develop. According to the author s experiment the embryo is entirely dormant above ground and it continues to be so even in the soil, until it begins suddenly to divide itself and develop on the 3rd or 4th day after the beginning of fructification.

The pod penetrated into sandy soil grows larger than that in the clayish soil, which proves repeatedly the appropriateness of sandy soil to peanut culture. The author obtained also quite satisfactory results to alter the size of the upper seed and the lower one artificially by altering the subterranean position of the pod. Thus it may be possible to infer from those results that not only physiogical causes such as the soil conditions and oxygen content in the soil, and mechanical causes such as subterranean obstructions may bring about changes in the development of the ovary and seed, but also the position of seeds in the pods executes certain influences on their development.

The total number of effective gynophores increases keeping pace with the growth of the plant, whereas the ratio of the total subterranean gynophores and fruits to the total of promising gynophores becomes lower during the later period of growth, which may be caused by the lesser chance of terrestrial gynophores to penetrate into the soil. The fact that the soil-penetration is most active during the early period of growth is the most important concern for the technique of peanut culture.

So far no reports have been issued with regards to the flower- and fruit-bearing habit of peanut. In this report it was proved that peanut produces a great number of flowers, especially in the runner type. Though they vary greatly from year to year and also according to the time of sowing, the bunch type showed a total of as many as 323.2 flowers and an average of 4.68 flowors per day during the flowering period of 69 days, and the runner type had as many as 1053.7 flowers in all and on overage per day 14.24 flowers during 74 days, in the 1932 experiment. It is of interest to compare these results to Richter's ones which counted approximately one flower a day during the flowering period of 62 days. However, only a few of the total number of flowers are able to penetrate into the soil and fructify, which are more commonly situated on the lower branches and the lower nodes, so that they are recognized consequently as the ones grown in the earlier stage of flowering period. It is natural therefore to conclude that the lower branches are generally more important in the cultivation of both the runner type and the bunch type. That is to say, the nodes near the base of the lower branch of the bunch type and the reproductive as well as the vegetative nodes near the basal position of the runner type constitute an important region for the fructification of the peanut. From these facts it may be inferred that the initial period of flowering plays an important rôle upon the yields of peanuts.

The rate of the ineffective flowers which do not produce any gynophores to the total is about 30 % in the both runner and bunch types. With regards to the structure of the flower, many earlier botanists and agronomists made erroneus descriptions. For examples, Bentham(3), Waldron(26), Bailay(2) and Robbins(18) speak of peanut as a plant having sterile or staminate and fertile flowers, while Poiteau, Neisler, Engler(6) etc. published the correct views. As the results of experiments, the author confirmed that most of the ineffective flowers mentioned above are not morphologically sterile but remain inactive due to the outer or inner causes preventing the fertilization or the development of the gynophore. The author found recently, however, an exceptional flower among them which is incompetent to pollinate and looks like a staminate flower, details on which will be reported in the future.

LITERATURE

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PLATE I

Explanation of Plate I

Fig. 1. Basal portion of peanut plant bearing gynophores at various stages of development (bunch type).

a. Flower bud, just before flowering.
b. Blossom, after flowering.
c. Blossom, withered.
d. Gynophore, penetrated into soil.
e. Gynophore, that has begun to fructify.

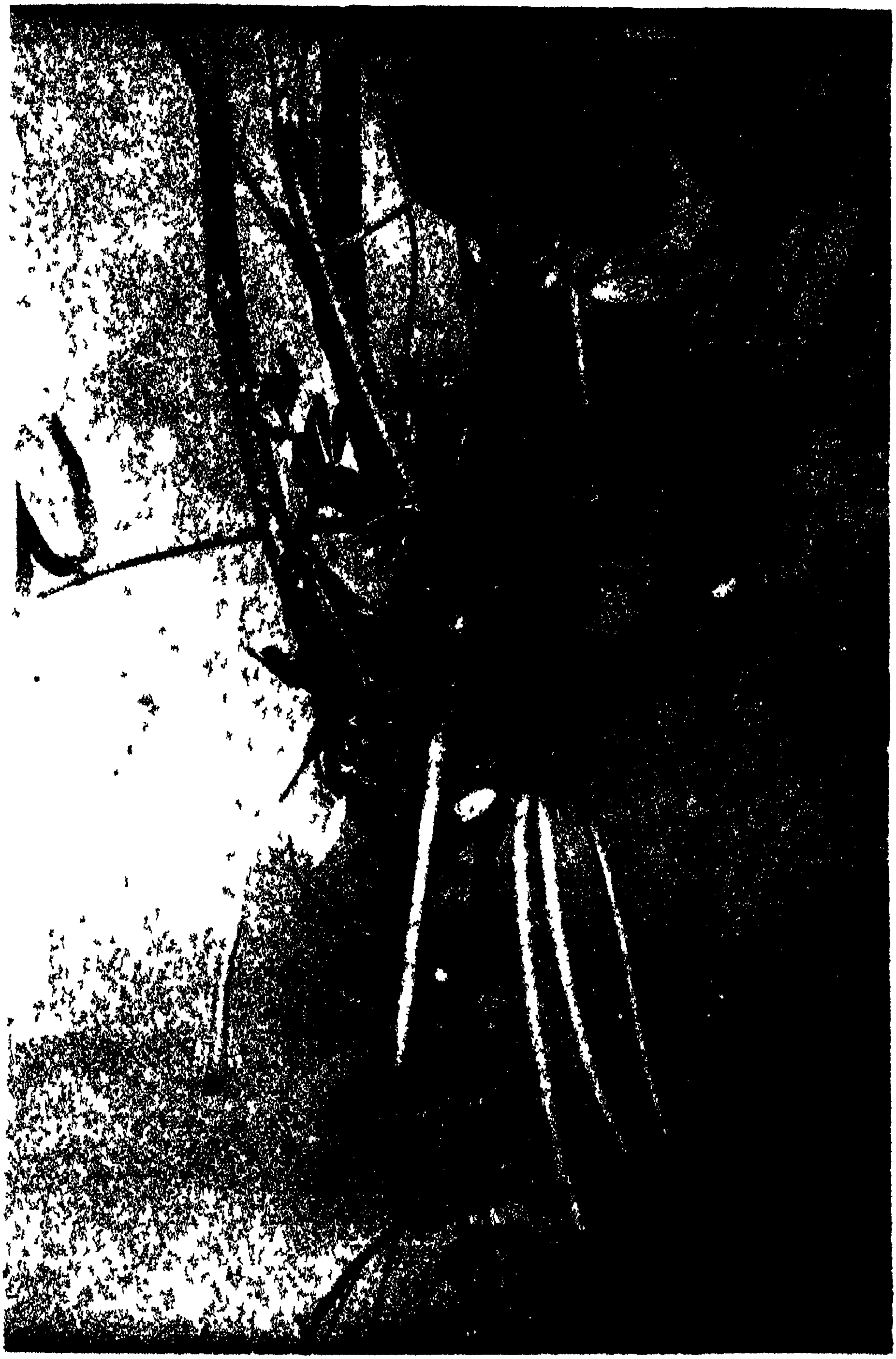

Fig. 1.

PLATE II

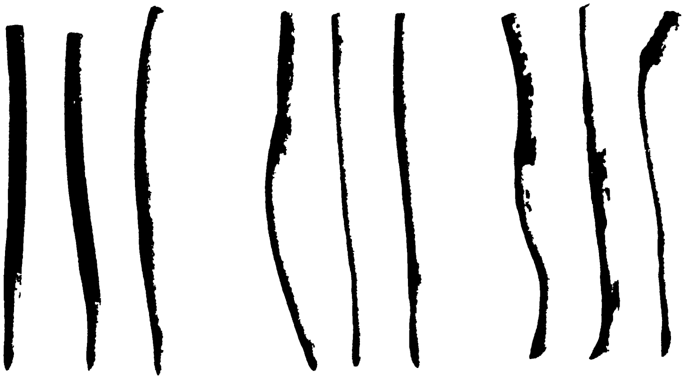

Fig. 2.

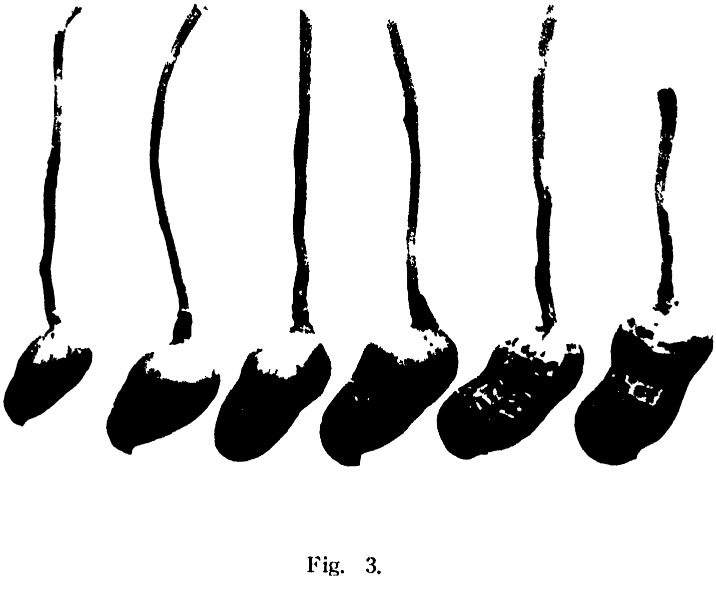

Fig. 3.

PLATE III

Explanation of Plate III

Fig. 4. Dormant embryo under terrestrial conditions. (200 ×)

Fig. 5. Embryo on 5th day after soil-penetration, still dormant. (200 ×)

Fig. 6. Embryo on 9th day after soil-penetration in which cell division has begun. (200 ×)

Fig. 7. Embryo on 11th day after soil-penetration in which it has begun rapidly to develop. (200 ×)

tions. The effect of low temperature was suggested by SAKAMURA(48) for the first time. He observed many abortive pollen grains in the plants of *Vicia Faba* which were covered with winter snow when they were carrying on the meiotic division of the pollen mother cells. To interplet this phenomenon, he suggested that the low temperature in this case seems to affect the plant to induce irregular meiosis. Similar assumption were adopted by BELLING,(1 2, 3) BORGENSTUM,(7) BLAKESLEE,(4) HÅKANSSON,(13) NAKAMURA,(42) KOSTOFF,(26) SAX,(50) WHITAKER,(67) MEDOWEDEWA,(32) etc. to explain the cause of occurrence of irregular meiosis, or abnormal pollen grains which were occasionally observed during the low temperature season.

DE MOL(36, 37) observed abnormal pollen grains of various kind in *Hyacinthus*, *Tulipa* and *Narcissus*, the bulbs of which were exposed to high or low artitificially deviced temperature, during the period of storage, in order to force blooming in early season. As to the cause of the occurrence of such abnormal pollen grains, he explained that the plants received some physiological stimulation as the result of this treatment, and this acted on the microspores of pollen tetrad as an agent in disturbing nuclear division, but not acting on the pollen mother cells. Recently,(38 39) however, he advanced an opinion maintaining that the plant body is affected by this treatment to change its sensitivity to temperature, and, in *Hyacinthus* especially, the occurrence of abnormal pollen grains is preceded by irregular meiosis of the pollen mother cells which is induced by the effect of low temperature, prevailing during the time of meiosis.

The evidence of laboratory experiments on the effect of low temperature on the meiosis was given by MICHAELIS,(33, 34) with *Epilobium* and *Oenothera*, and by SHIMOTOMAI(53) with *Liriope* and *Scilla*. They succeeded to cause abnormal meiosis of the pollen mother cells by exposing the plants to the temperature suddenly lowered. It is worthy of note that MICHAELIS,(34 35) succeeded by pollination with the operated pollen grains to obtain some progenies with unexpected chromosome number. RUDOLF and SCHMIDT(47) studied the unstability of meiosis with certain species of *Oenothera*. They found it became very con-

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I. INTRODUCTION

The possibility of artificially induced mutation in plant life is no longer a matter of question, since recent investigators have succeeded in causing it by the application of physical or chemical stimuli. The investigation had opened a new field in the study of cytology and genetics, and many interesting results have been presented to solve the question of what response can be expected from an application of such stimuli, such as certain kinds of rays, extreme temperatures, narcotic substances, etc.. Such stimuli often cause the abnormality of the meiosis or mitosis, and if such abnormality is to be the first and the most effective process to cause the chromosomal mutation, as interpreted by many authors, similar abnormal cases must be found in nature without any notice, since mutation generally occurs in nature, not under unusual environment but under almost normal condition. The aim of the present study is to find out if minor change of environment, such as the rise or drop of air temperature, may cause a conspicuous disturbance to the meiotic division of the pollen mother cells. If such is the case, later processes of gametic inconstancy inducing a chromosomal mutation may follow.

The survey of literatures on temperature effects which gives stimulations on the meiosis of plants, bring some interesting suggestions. The effect of low temperature was suggested by SAKAMURA(48) for the first time. He observed many abortive pollen grains in the plants of *Vicia Faba* which were covered with winter snow when they were carrying on the meiotic division of the pollen mother cells. To interplet this phenomenon, he suggested that the low temperature in this case seems to affect the plant to induce irregular meiosis. Similar assumption were adopted by BELLING,(1 2, 3) BORGENSTUM,(7) BLAKESLEE,(4) HÅKANSSON,(13) NAKAMURA,(42) KOSTOFF,(26) SAX,(60) WHITAKER,(67) MEDOWEDEWA,(32) etc. to explain the cause of occurrence of irregular meiosis, or abnormal pollen grains which were occasionally observed during the low temperature season.

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spicuous in the late autumn when air temperature falls often very low.

On the effect of high temperature on the meiosis of the pollen mother cells, there are several reports of laboratory experiments. STOW(56 57) explained that, under the climate of Hokkaido, the meiotic division of the pollen mother cells of certain varietis of the cultivated potato become irregular when the temperature rises to 25–36°C.. SAKAMURA and STOW(40) exposed *Gagea lutea* to the temperature of 30°C. for 15 hours or longer in winter. By this treatment, irregular meiosis of the pollen mother cells was induced, and it was followed by the formation of viable pollen grains with abnormal chromosome number. Similar experiments were made by TAKAGI(61) with *Lychnis*, by BLEIR(6) with *Triticum*, and by KOSTOFF(27) with *Capsicum*. They succeeded also to cause abnormal meiosis by exposing the plants to abnormally high temperature.

The relationship between high temperature and non-conjugation of chromosomes was studied by HEILBORN(14) with apple varieties, and by KATAYAMA(21) with F_1 *Triticum-Aegilops* hybrid. In these plants, high temperature was effective to increase the number of non-conjugating chromosomes. There are interesting reports about the effect of temperature on the microsporogenesis. MATSUDA(31) proved that the giant pollen grains of *Petunia* are formed by the union of pollen mother cells which is induced by the influence of high temperature. STOW(58 59) and DE MOL(38) succeeded in obtaining emblyosac-like giant pollen grains in *Hyacinthus* by exposing the plant to high temperature under the controled environment. SAX(51) placed *Tradescantia* in thermostats of both high and low temperature, and also cut branches of *Psudolarix amabilis* in a warm glass house. In this experiment, he observed the occurrence of abnormal nuclear divisions of microspores which indicates the influence of extreme temperature upon the synchromization of cytoplasmic movement and nuclear activity.

The results of these laboratory experiments reviewed above, show clearly that abnormally high or low temperature does affect the meiotic division of plants, and, in some cases, the pollen grains obtained by such treatment gave a start to the origination of new plants with polyploid or odd-numbered chromosomes. From these facts, one can easily conclude that an extreme temperature offers a chance to cause artificial mutation in plants. However, the temperature applied in these experiments is beyond the daily range of normal climatic condition, and that does not show how air temperature influences the meiosis under the normal condition. On the other hand, we have several data to suggest that the temperature which disturbs the meiosis of some plants is not necessary to be so extreme as those applied in these experiments, since we have instances where plants seemed to be disturbed in their meiosis by the effect of slight changes of temperature during the normal season.(10, 12, 46)

STOW(56, 57) discussed this problem in reference to the tomato and he alluded to seasonal change of temperature as a cause of chromosomal abnormality, but it is premature to accept his conclusion as a general rule to interpret a phenomenon of this kind. His conclusion as to the direct effect of air temperature on the meiosis was opposed by LONGLEY and CLARK(30) who credit the hybrid as the principal cause for bringing about irregular meiosis. To explain the cause of irregular meiosis found occasionally in *Disporum sessile*, WASHIASHI(65) exposed plant materials to the thermostat temperature of 7°C. for 65 and 106 hours, and he obtained the result that the meiosis was disturbed markedly when followed by the formation of pollen grains with unusual chromosome number. This experiment lead him to a conclusion that extremely low air temperatures, affect the meiosis of this plant. If we can prove that such critical temperature for some plants lies within the range of normal temperature of the season, it might faciliate to solve the origin of mutation.

In the previous paper,(43) the present author reported that a certain, diploid strain of *Impatiens Balsamina*, LINN. shows daily variations in the regularity of meiosis of the pollen mother cells when followed by the occurrence of abnormal pollen tetrads and pollen grains that varied in percentage. Observing that the unstability in this case was in accordance with the daily changes of air temperature, under which meiosis was carried out, he concluded that the effect of high air temperature in summer may be the principal cause of this peculiar phenomenon. In order to confirm this conclusion, he repeated the experiment. The results here presented are intended to show how the meiosis of the pollen mother cells is sensitive to the high air temperature within the range of daily changes. Besides this, interesting cytological phenomena were found to distinguish various types of abnormal meiotic division.

The brief accounts of this paper were read before the 10th. meeting of the Japanese Association(45) for the Advancement of Science, and the 7th. meeting of the Japanese Genetic Association,(44) both held at Taihoku in 1934.

II. MATERIALS AND METHODS

The plant materials used in the autumn of 1931 were raised from the open-pollinated seeds which had been collected from one of the three initial balsam plants used in the former study.(41) One individual plant of this experiment was self-pollinated in the glass house. The progenies raised from this plant, and the others obtained by self-pollination from year to year were used as the materials for the following experiment. These progenies are denoted in this paper as Strain 1 to distinguish them from other strains which were used once in the experiment described in chapter X. Though the balsam plant is generally regarded as a hard-seeded plant,(25) the present author observed that the seeds sown in soils immediately after the collection germinated always very soon. Thus we are able to raise two or more generations of balsam plants in a year, if necessary. The total number of the plants raised during the experiment exceeded three hundred, and the materials were brought down to the sixth generation. All offsprings in every generation bred true with the exception of only three abnormal individuals. Besides these progenies, the author made observations with other individuals coming apparently from the same line found in the field where the initial plant materials were first found. They also bred true. These facts show that the present material is a genetically pure strain having a similar constitution to the beginning of the experiment. Further evidence of this assumption is shown by the special character of the floral organ of this plant. In the alabaster stage of this plant, five anthers closely cover the stigma, and they split open shedding pollen grains on the stigma before the petals begin to open. Flowers sometimes remain unopen till late, and the developed ovary is enveloped by dried petals. These cleistogamic characters seem to prevent cross pollination and resultant intermixing with other strains.

In order to examine the effect of temperature upon the meiosis of the pollen mother cells under natural conditions, the cytological materials were collected from plants in the glass house as well as from those placed outdoors, and the mode of meiotic division, or of the pollen tetrads were compared. In some cases where high temperature was not required in the hot season, plants were put in the corridor of the laboratory instead of putting them outdoors. The observation of plants placed under controlled temperature in the laboratory was also made to make the test more accurate than the experiment conducted by the method mentioned above. As no control of temperature was devised in the glass house, the temperature in it changed from time to time to response the change of outside air temperature. As to the temperature of the glass house and outside, marked difference was observed in clear hot days, while the difference was not great in night or in cool, cloudy days. The glass house used in the study of 1931 was a small propagation house not well ventilated, while the house used in the studies of 1932 and later was a large one covered by vita glass admitting the penetration of ultra-violet rays and it has many windows for ventilation. The variation of temperature in the former was eventually greater than in the latter. Consequently, the plants in the latter house must have received more natural environmental conditions for growth.

The temperature in the glass house and the corridor was recorded with the aid of the thermograph and a Six's thermometer. In the experiment of 1934, the outdoor-temperature was recorded directly by a Six's thermometer suspended in a thermoscreen standing in the same place where the plant materials were put. In the other cases of the experiment, the outdoor temperature was not observed, but the data reported by the Taihoku Meteorological Station were used for discussing the experimental result.

III. THE DAILY OCCURRENCE OF ABNORMAL POLLEN TETRADS AND ITS RELATIONSHIP TO THE AIR TEMPERATURE

The author reported(41) that, the present strain of the balsam plant showed variation in the ratio of the occurrence of abnormal pollen tetrads in connection with the change of temperatures on a day when the cytological materials were fixed. In the autumn of 1931, he made a further study to accumulate more precise data.

Six plants raised outdoors were used as the experimental materials. The lot was divided into two groups, three plants in each group. At the beginning of the study, two plants of each group were examined whether they have an equal mode of tetrad formation or not. A number of buds on the different hranches of each plant were examined in this test. This preliminary observation showed that there

TABLE I.

PRELIMINARY OBSERVATION OF THE MODE OF TETRAD FORMATION IN THE PLANT MATERIALS RAISED UNDER THE SAME ENVIRONMENT.

Nö. of plant	Position of flower bud	Nos. of pollen tetrad	
		Normal	Abnormal
1	third branch	300	0
2	main stem	300	0
3	main stem	300	0
	first branch	300	1
	third branch	300	1
4	second branch	300	0
	third branch	300	0
	fourth branch	300	0

is no marked difference in all buds examined, as shown in Table I. This fact must indicate that the present materials respond equally to the same environmental conditions, under which they were growing.

In the afternoon of Sept. 23rd., one group of plants was taken into the glass house (Group *A*), and another group was put outdoors near the glass house (Group *B*). At 5 P.M. of Oct. 5th., one of each lot of plants was removed to interchange their position, an outdoor plant being taken inside and an inside plant being taken out.

Young flower buds were collected every day at about 11. A.M., and their anthers were smeared at once in the aceto-carmine solution for the examination of pollen tetrads. In certain cases, permanent preparations were made. About two hundred pollen tetrads of each bud were observed, and the percentage of abnormal ones among the total number were determined.

Throughout the course of the experiments, the air temperature changed day by day with marked difference. This condition favored

TABLE II.

THE OCCURRENCE OF ABNORMAL POLLEN TETRADS IN THE GLASS HOUSE AND IN THE OUTDOOR MATERIALS.

Date of observation (1931)	Glass house				Outdoor			
	Maximum temperature		Percentage of abnormal tetrads		Percentage of abnormal tetrads		Maximum temperature	
	Two days before	One day before	Plant *b*	Group *A*	Group *B*	Plant *a***	One day before	Two days before
	c	c	%	%	%	%	c	c
Sep. 26	36.5	39.5		95.6	68.1		31.7	29.4
28	40.0	41.5		90.4	52.8		33.0	31.5
29	41.0	43.0		90.9	51.2		33.0	33.0
Oct. 3	32.0	28.0		0.9	1.0		24.9	25.1
5	41.0	39.5		86.6	0.3		30.5	28.9
6	39.5	38.0	1.9	—	0.0	60.8	30.0	30.5
8	40.0	41.0	81.3	83.6	24.2	39.5	32.5	31.4
10	38.0	28.0	1.6	4.2	—	—	25.3	29.5

* the plant moved into the grass house from the outdoor in the evening of Oct. 5th.

** The plant moved outdoors from the glass house in the evening of Oct. 5th.

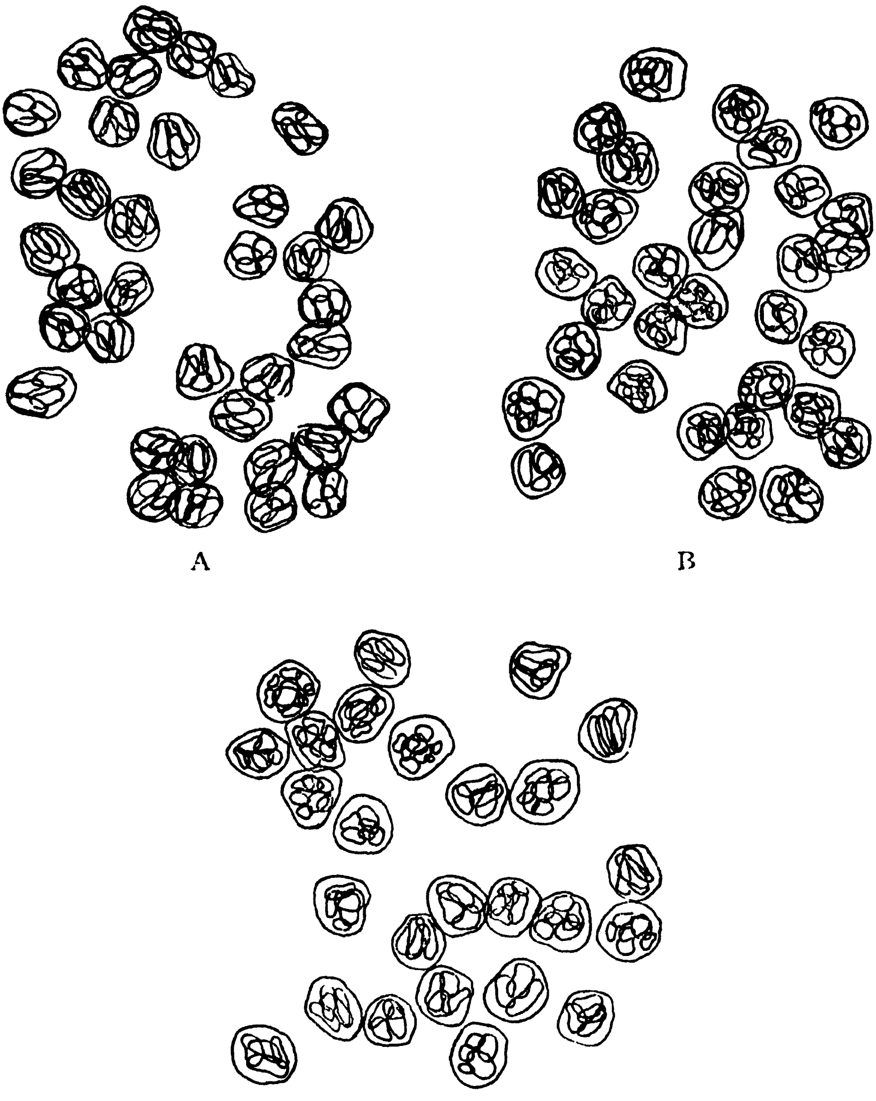


Fig. 1.

A part of pollen tetrads in loculi, showing the daily changes in the occurrence of abnormal pollen tetrads. **A—B**, showing marked difference in the abnormality of pollen tetrads in two buds which were collected from the same individual in the glass house on different days; **A**, the pollen tetrads observed on Oct. 3rd., only 0.9% of them being abnormal; **B**, the pollen tetrads observed on Oct. 5th., 86.6% of them being abnormal; **C**, the pollen tetrads observed in an outdoor-material on Sep. 29th., 51.2% of them being abnormal.

the examination of the expected effect of air temperature upon meiosis. The result of the observation is summerized in Table II, and some examples of the observed pollen tetrads are shown in Fig. I and Plate IV [I], 1-2.

From examination of this table the following facts can be seen.

1. Daily variations in the percentage of abnormal pollen tetrads are found in both groups.
2. When abnormality is observed in the outdoor materials, similar abnormality is also found in the glass-house materials, however, the latter indicates always higher percentage of abnormal pollen tetrads.
3. Some days, the percentage becomes very low, i. e. 0-4.2%. And such low percentage is met with more frequently outdoors than in the glass house.

This peculiar phenomenon can not be due to the difference in the individuality of plants, but it must be caused by the effect of some environmental factors. If some environmental factor can affect the plant in such a way, the factor must prevail both outdoors as well as in the glass house, but its intensity must be different in each place, showing daily change. In examing such environmental factors, only two seem to be responsible to cause such changes. The first is the intensity of solar radiation and the second is the air temperature.

If the intensity of solar radiation is the factor which influences the meiosis, we can suppose that the low intensity may disturb the meiotic division, since it is conceivable that solar intensity in the glass house is always lower than that outdoors. But this supposition does not hold good, because, the present plants if placed in the corridor, or in the room always showed normal meiosis,- see later chapters.

Then, attention must be paid to the air temperature. Plant *a* (one of the glass-house materials) and plant *b* (one of the outdoor-materials) were changed in their places at 5 P. M. on Oct. 5th., the former being taken outdoors and the latter brought inside. In the observation of the next morning, the former showed a very high percentage of variation, while the latter showed a very low percentage as well as the plants of Group *B*. Three days after, plant

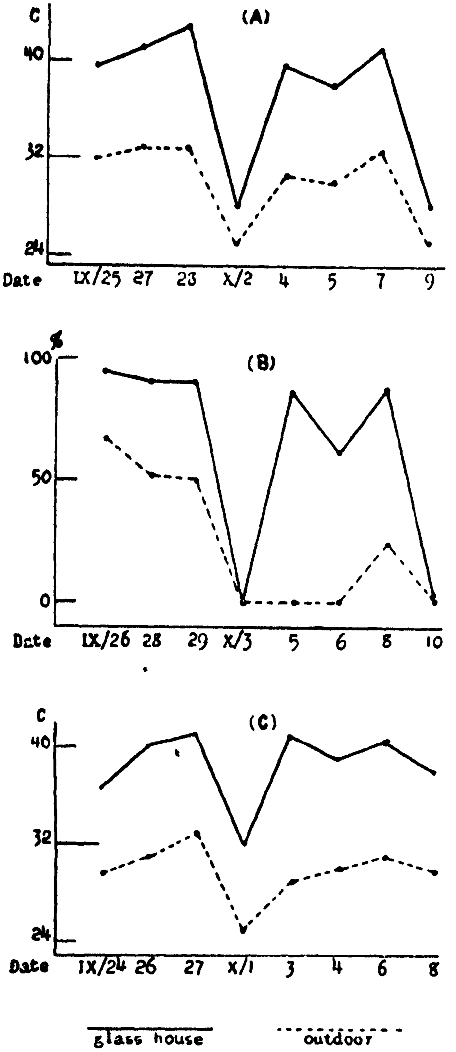


Fig. 2.

The daily changes in the occurrence of abnormal pollen tetrads contrasted with the maximum day temperature. **A**, the maximum temperature of the preceding days of examination of pollen tetrads; **B**, the percentages of the occurrence of abnormal pollen tetrads; **C**, the maximum temperature of two days before the days of examination of pollen tetrads.

a showed a lower percentage than Group *A*, and Plant *b* showed a higher percentage than Group *B*. These results also indicate that the influence of the changed condition of original place upon the tetrad formation lasted for one day or two, but it disappeared three days after. From this fact we can suppose that the abnormal pollen tetrads coming under observation were really disturbed their meiosis at last one or two days before. If this postulation is true, the percentage of abnormal pollen tetrads of certain days must have a close relationship with the air temperature of one or two days before.

This relationship is shown in Fig. 2. Curve " A " and " C " represents the maximum temperature of one day and two days before, respectively, and curve " B " represents the percentage of abnormal pollen tetrad on the day of observation. The straight lines show the observation in the glass house, and the broken lines show the observation outdoors. From examination of these curves, we can easily find the presence of a close relationship between curve "A" and " B."

According to the facts shown by these figures (also from Table II), more than 60% of abnormal pollen tetrads occured in the glass house when the maximum temperature of one day before was higher than 38°C.. Outdoors, 24% or more abnormal pollen tetrads were counted when the maximum air temperature of the preceding day was higher than about 32°C.. The temperature data used in drawing outdoor curves were not directly observed, and the actual temperature affecting the plants changed in its intensity from time to time during the course of the experiment. Furthermore the meiotic stage which was influenced by the temperature may be somewhat different in each bud. This condition makes it difficult to establish precisely the relationship between the percentage of abnormal pollen tetrads and the effect of actural temperature. But, judging the experimental data, the author considers that the higher the temperature and the longer the duration of high temperature, eventually the higher the percentage of abnormal meiosis followed by the formation of abnormal pollen tetrads.

Besides this fact, the occurrence of a higher percentage of abnormal pollen tetrads is generally associated with more extreme irregularity. Table III shows the variation of the number of microspores in each pollen tetrad in preparations used in the preceding study. The data are classified into four groups according to the percentage

TABLE III.

VARIATION IN THE NUMBER OF MICROSPORES OF POLLEN TETRAD.

Occurrence of abnormal tetrads \ Nos. of microspores	1	2	3	4	5	6	7	8	9	10	11	12	13
% 87-96	0.65	0.09	0.49	8.60	15.58	21.65	23.69	15.75	7.14	4.79	0.81	0.66	0.10
45-68	0.00	0.00	0.00	40.38	15.08	12.47	16.81	9.19	3.56	1.87	0.00	0.00	0.00
24-39	0.00	0.00	0.00	68.14	10.06	10.38	8.56	1.90	0.96	0.00	0.00	0.00	0.00
0.5-4	0.00	0.00	0.00	97.53	2.39	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00

of abnormal pollen tetrad in each preparation, and average percentage of each group is given in the table.

The table shows that the high percentage of abnormal pollen tetrads is always associated with the high variation of microspore formation. The usual abnormality in this case is polyspory, while hypospory is a rare phenomenon. This result shows that intensity of temperature acts not only upon the percentage of abnormal tetrad formations but also upon the variation in the number of microspores.

From the results of the studies, it is sufficient to say that, under the natural condition of outdoors or in the glass house, a slight rise of air temperature is good enough to affect a large number of pollen mother cells to cause abnormal meiosis, and also the extreme irregularities of microspore formation.

IV. THE RELATIONSHIP BETWEEN THE OCCURRENCE OF ABNORMAL POLLEN TETRADS AND THE MAXIMUM AIR TEMPERATURE OF THE PRECEDING DAY

The result of the experiments given before has shown that the occurrence of abnormal pollen tetrads is related to the uprise of air temperature of a day before. But, since the data was not clear enough, further experiment was conducted to obtain further evidence. The materials consisted of four plants which were divided into two groups, *A* and *B*, respectively, and their places were changed from the corridor of the laboratory to the glass house, or vice versa, in order to expose them to different air temperature conditions. The exact times when each group was changed were as follow.

	10. A.M. VI/30	6 P.M. VII/1	6 P.M. VII/2	6 P.M. VII/4	6 P.M. VII/5
Group *A*	C	G	C	G	O
Group *B*	C	G	C	C	O

C, corridor; G, glass house; O, outdoor.

The percentage of abnormal pollen tetrads in each plant was counted at 10 A. M., every day. Table IV is to show the final result of the observation. The percentage given in the table was calculated from two hundred pollen tetrads, and the temperature data were obtained by the direct observation.

TABLE IV.

THE OCCURRENCE OF ABNORMAL POLLEN TETRADS WITH REFERENCE TO THE MAXIMUM DAY TEMPERATURE.

Date of observation	Abnormal pollen tetrads in Group *A*			The maximum temperature of the places where both groups were put		Abnormal pollen tetrads in Group *B*		
	No. 71	No 73	Mean	Group *A*	Group *B*	Mean	No. 72	No. 74
	%	%	%	C	C	%	%	%
VII/1	—	—	—	30.0	30.0	-	—	—
2	0	1.4	0.7	**34.0**	**34.0**	0.3	0	0.5
3	**26.8**	**32.1**	**29.5**	29.5	29.5	**30.8**	**30.2**	**31.3**
4	1.0	1.0	1.0	29.5	29.5	0	0	0
5	—	—	—	**34.0**	30.0	—	—	—
6	-	**33.1**	**33.1**	—	—	4.0	4.0	—

The plants of both groups were put in the same place till 6 P.M. July 4th.. During this period, the variation in the percentage of abnormal pollen tetrads was similar in all plants every day. After 6 P. M., July 4th., group *A* was placed in the glass house, and a distinct difference in the percentage was observed between both groups. The occurrence of distinct abnormality in the pollen tetrads of the present experiment, was always on the day following the highest temperature (34° C.), and when the maximum temperature was 30° C. or lower, the percentage of abnormal pollen tetrads the next morning was very low or zero.

This experiment shows that the meiotic division is disturbed on the day of high air temperature, and the abnormal pollen tetrads are formed as the final product up to the next morning, but the effect of high temperature does not continue for two days. This result agrees well with the conclusion given in the preceding chapter.

V. THE RELATIONSHIP BETWEEN AIR TEMPERATURE AND ABNORMAL MEIOSIS

The meiosis of the pollen mother cells of the plants grown outdoors was examined day by day in order to confirm its relationship to the daily changes of air temperature. Many abnormal behaviors of chromosomes were found as described in the later chapter.

Simplifying the matter, only the percentage of abnormal figures is contrasted in table V with the maximum temperature of the days when observation was made. All materials were collected between 3 P. M. and 5 P. M., and they were smeared at once in Belling's aceto-carmine solution.

During the experiment, the maximum day temperatures were always recorded at the time between 11 A. M. and 2 P. M.. The temperature data given in the table were obtained from the record indicated by a Six's thermometer suspended into a thermometer screen that stood near the plant materials.

TABLE V.

THE OCCURRENCE OF ABNORMAL MEIOSIS IN THE POLLEN MOTHER CELLS REFERED TO THE MAXIMUM, DAY, AIR TEMPERATURE

Date of observation (1934)	Maximum temperature (C)	First meiosis		Second meiosis	
		Total number of observed figures	Percentage of abnormal figures	Total number of observed figures	Percentage of abnormal figures
VI/12	32.5	154	% 8.4	53	% 39.8
VI/14	27.0	132	1.5	200	0
VI/15	31.5	116	0	—	—
VI/16	31.5	120	1.5	98	8.2
VI/23	32.6	76	21.5	103	52.4
VI/24	34.2	122	24.6	64	85.9
VI/25	33.8	117	11.1	95	97.9
VI/26	33.5	35	11.4	128	93.0
VI/27	33.5	106	15.1	76	82.9

As the table clearly shows, the occurrence of abnormal meiosis corresponds to the rise of air temperature, and the second division was more strongly disturbed than the first division. The high percentage of irregular figures was counted at a maximum temperature higher than 32.5° C.. When the temperature is lower than this critical point, most of the pollen mother cells show normal meiosis.

Table VI shows the result of another experiment. In this case, the cytological materials were collected, at about 2 P. M. from the plants grown outdoors as well as in a glass house, and the percentage of abnormal figures in the first division of the pollen mother cells was counted.

TABLE VI.

PERCENTAGE OF ABNORMAL MEIOSIS IN THE PLANT MATERIALS GROWN IN THE GLASS HOUSE AND OUTDOORS.

Date of observation	Glass house		Outdoor	
	Maximum temperature	Abnormal meiosis	Maximum temperature	Abnormal meiosis
	C	%	C	%
Sep. 26, 1931	40	83.2	31.5	15.1
Sep. 29, 1931	32	19.6	25.9	0
July, 22, 1932	35*	39.0	35.9 *	47.0
July, 28, 1932	40	93.1	31.1	26.9
July, 30, 1932	35	63.1	31.0	3.5

* This degree of temperature indicates the maximum attained up to 11 A.M. when the glass house materials were collected. ** The outdoor materials were collected at 2 P. M. when the temperature of the day attained the maximum.

As the table shows, the percentage of abnormal meiotic figures in the glass-house materials is generally higher than that counted in the outdoor materials. And, in both cases, marked abnormality is observed at maximum temperature above 31.5° C., and the uprise of temperature is associated with an increased percentage.

VI. THE EFFECT OF ARTIFICIAL TEMPERATURE ON THE MEIOSIS

In the preceding chapters, the author proved that the abnormal meiosis of the pollen mother cells occurs under the natural condition, outdoors or in the glass house, when the air temperature attains to certain point. This is not sufficient to prove how temperature acts directly upon the plant. In order to arrive at a clearer understanding of this point, he made further study in the laboratory with the aid of a specially devised thermostat for the use of physiological study. The walls of this thermostat are glazed with vita glass to permit the penetration of sun beams. Holes of about 1 inch in diameter were opened both on the ceilling and on the floor, to admit free air circulation. Constant temperature was obtained at will by the aid of an electric heater and the expansion coils of an ammonia compressor installed in the next room. The plant materials were kept in this thermostat at a constant temperature for 5 hours, and then, they were taken out in order to get young anthers smeared at once in the aceto-carmine solution for the examination of the meiotic division. To avoid the influence of outdoor temperature, the plant materials were put in the corridor of the laboratory for about 24 hours before the commencement of the treatment.

As the detail of this experiment was reported in the Japanese Journal of Genetics,(44) the author will give here only a brief description. Table VII summerises the result of the experiments as to the percentage of abnormal figures which were observed at different temperatures during the treatment.

TABLE VII

THE RELATIONSHIP BETWEEN TEMPERATURE AND ABNORMAL MEIOSIS.

Experiment	Temperature (C)	Numbers of meiotic figures observed					
		Division I			Division II		
		Total	Abnormal	Abnormal / Total %	Total	Abnormal	Abnormal / Total %
I	24-25	34	0	0	101	0	0
II	27-28	199	4	2 0	61	2	3 0
III	29 30	163	12	7 5	—	—	-
IV	31-32	48	7	11 0	155	61	39 0
V	32-33	93	15	15 0	149	143	95 0

As the table shows, the meiosis is practically or quite normal at the temperature below 28° C., while it is irregular at above 30° C.. These irregularities become extreme with the rise of temperature, not only in the number of affected pollen mother cells, but also in the degree of irregularity observed in each cell.

The principal types of the abnormality observed in these cases are as follow:—

At the first meiosis: Lagging of a few bivalent chromosomes; too early, or too late disjunction of several gemini; appearence of univalent chromosomes before the metaphase; scattering over of all chromosomes throughout the spindle, or throughout the cytoplasm; random disjunction; etc..

At the second meiosis: Too early splitting; scattering over of most of the chromosomes in the cytoplasm; wandering of a few chromosomes in the cytoplasm; formation of a giant equatorial plate consisting of univalent chromosomes; random splitting; union of two equatorial plates or of the poles of different spindles; random gathering of chromosomes in the late anaphase; etc..

Temporary influence of the high temperature were proved in Experiment IV. In this experiment, a high percentage of irregular meiosis was counted immediately after the treatment. After this observation, the materials were put into the corridor of the laboratory where temperature varied from 27° to 28° C, and the observation was made again at 10 A. M. of next morning. In this case, a very reduced percentage of abnormal figures were obtained, i. e. only 13 abnormal ones

TABLE VIII.

Frequency of the Number of Microspores of Follen Tetrads in the Balsam Plants which were exposed to the Temperature of 31° to 32° C. for 5 Hours on May 30th.

Date of observation \ Number of microsopre	3	4	5	6	7	8	Total nos. of pollen tetrads	Abnormal / Total
May 31, 10 A. M.	1	139	41	14	4	1	200	% 35.0
June 1, 2 P. M.	0	200	5	2	0	0	207	3.4

among 153 figures of both divisions. This fact shows that the effect of high temperature almost disappeared before the next morning. The observation of pollen tetrads shows also a similar condition. In this case, the effect of high temperature appeared the next morning after the treatment, and it disappeared before the afternoon of two days later. Table VIII indicates this relationship clearly.

VII. THE EFFECT OF HIGH TEMPERATURE ON THE FORMATION OF POLLEN GRAINS

The author(41) pointed out that, in the present strain of the balsam plant, the portion of the perfect and imperfect pollen grains, and the size and shape of the perfect pollen grains are not always definite. In order to confirm the relationship between this phenomenon and temperature, the following study was made in the autumn of 1933. The experiment was started from Oct. 1st. and ended on Nov. 3rd.. The experimental materials used in this study are two individuals of Strain 1. At the commencement of the experiment, by the Belling's smear method, the author found out the buds which were carrying on the first meiosis at this time. He removed from both plants the larger sized flower buds, and the buds left on the plants were only those, having the meiosis of pollen mother cells not advanced more than the first metaphase.

One of these plants was exposed to 34.5°-35°C. in the thermostat for 5 hours, every day between 9 A.M. and 2 P.M.. This exposure was repeated for 5 days. During the same time of this exposure, the other plant, used as a control in this experiment, was placed in the laboratory where the thermostat was set.

Before and after the treatment, both plants were placed outdoors. During the experiment, the room temperature of the laboratory varied from 25° to 25.9°C., and that of the outdoors from 21.8° to 25.9°C..

As soon as the last exposure was finished, the author examined the stage of meiotic division of several flower buds of both materials, and he determined the size of the flower buds that were carrying on the first meiosis of the pollen mother cells. Among the flower buds of the exposed and the controlled plants, those that were larger in size than the buds carrying on meiosis, were marked as Lots *A* and *a*, respectively. And the remainders of both plants, i. e., of smaller size, were marked as Lots B and *b*, respectively. Then, we can assume that Lots *A* and *a* consist of the flower buds which finished the meiotic division of the pollen mother cells during the days of exposure, while Lots *B* and *b* consist of those, the meiosis of which were in prophase, or in the resting condition, during the same period. If pollen sterility is preceded by irregular meiosis it is caused by the effect of high temperature, the mature pollen grains of Lots *A* and *B* must show higher sterility in comparison with those of Lots *a* and *b*. The comparison of sterility between Lots *A* and *B* will indicate to us how high temperature affects the different stages of meiosis of the pollen mother cells.

The flowers began to open on Oct. 23rd.. Some five hundreds of pollen grains in each anther of newly open flowers were examined day by day with the aceto-carmine solution. And the proportions of sterile and viable pollen grains were determined. The pollen grains defined as sterile in this experiment are those which were empty, or stained faintly showing disintegration of the cell contents. Table IX summerizes the result of examination.

In Lot *A*, a very high sterility such as 51.6% in average is observed, and the sterility in most of the anthers ranges from 16.6 to 100%. Such a high sterility is not found in any flowers of Lot *a* of the control, with the exception of flower No. 5. Generally, the sterile pollen grains found in Lot *A* vary in size and shape as shown in Fig. 3, *D* and Pl. IV [I], 5, indicating that they were formed after abnormal cell division. From this fact, it is clear that the effect of high temperature is marked when the meiosis of the pollen mother cells is advanced more than prophase. Flower No. 5 is the only one which shows very high sterility among the flowers of the control. The sterile pollen grains in this case are larger and more uniform

TABLE IX.

STERILITY OF POLLEN GRAINS IN THE PLANT REPEATEDLY EXPOSED TO HIGH TEMPERATURE. (34.5°-35.° C.

(A) Sterility observed in the exposed plant.

Lot	Date of flowers opened	No. of flower	No. of anther I	II	III	IV	V	mean
			%	%	%	%	%	
A	Oct. 23	1	21.4	16.8	12.4	8.4	8.2	14.04
	24	2	26.4	23.8	22.6	18.8	13.2	20.96
	25	3	50.0	41.8	35.6	26.0	22.0	35.08
	"	4	96.0	92.6	90.8	73.0	62.8	83.04
	27	5	100.0	99.8	99.4	97.8	25.6	84.52
	28	6	21.8	20.6	17.2	16.8	16.6	18.60
	30	7	93.0	46.0	37.0	36.6	17.3	46.98
	"	8	99.4	21.2	21.8	18.6	18.4	36.48
	"	9	100.0	100.0	99.6	99.2	99.2	99.60
	"	10	91.8	40.0	30.8	28.8	—	47.85
	"	11	89.6	85.8	77.8	51.8	—	76.25
	31	12	47.2	46.2	43.2	35.0	28.6	40.04
	"	13	98.6	93.0	96.6	95.0	51.4	87.92
	"	14	65.2	30.0	29.6	18.8	14.8	31.68
		Mean						**51.64**
B	Nov. 1	15	21.2	16.6	9.2	9.2	9.2	13.08
	"	16	4.6	4.2	3.4	2.4	1.4	3.20
	"	17	6.6	5.8	5.6	5.4	3.2	5.32
	"	18	4.6	3.4	3.2	2.2	2.0	3.08
	"	19	11.0	4.4	3.2	3.2	2.6	4.88
	"	20	4.6	3.6	2.6	1.4	1.4	2.72
	"	21	5.6	2.2	1.4	1.0	0.4	2.12
	"	22	4.4	3.2	1.6	1.2	0.6	2.20
	"	23	6.4	4.2	2.2	1.4	1.2	3.03
	"	24	7.0	5.6	4.6	2.2	1.4	4.16
		Mean						**4.38**

(B) The sterility observed in the control.

Lot	Date of flowers opened	No. of flower	No. of Anther I	II	III	IV	V	mean
			%	%	%	%	%	
a	Oct. 25	1	7.4	5.2	2.0	1.4	1.2	3.44
	”	2	13.2	5.4	2.8	2.6	2.0	5.20
	”	3	11.4	5.2	5.0	3.4	3.2	5.64
	”	4	10.2	9.2	7.0	4.0	1.8	6.44
	27	5	55.1	18.6	13.4	7.0	4.8	19.78
	”	6	14.8	14.4	13.4	8.0	6.0	11.32
	”	7	12.8	12.4	12.4	9.4	6.4	10.68
	”	8	9.2	7.4	7.0	5.2	2.6	6.28
	28	9	10.4	9.2	6.6	6.4	5.5	7.62
	”	10	6.6	5.2	2.8	1.8	1.3	3.54
	”	11	7.8	2.2	2.0	1.4	1.0	2.88
	”	12	3.4	1.6	1.4	1.0	1.0	1.68
	30	13	13.2	8.4	5.0	2.2	1.4	6.04
		Mean						**6.96**
b	Oct. 31	14	6.6	3.0	2.4	2.6	2.0	3.32
	Nov. 2	15	10.8	5.6	3.8	2.0	1.4	4.72
	”	16	11.2	8.4	5.6	5.3	2.4	6.58
	”	17	3.8	2.0	1.8	1.4	1.2	2.04
	”	18	7.2	4.6	1.4	1.4	1.2	3.16
	3	19	6.2	2.8	2.6	2.0	0.8	2.88
	”	20	10.2	6.0	5.6	5.4	3.8	6.20
	”	21	7.4	5.6	3.2	2.2	1.8	4.04
		Mean						**4.11**

in size, and they take more regular shape in comparison with those of Lot *A* (Fig. 3, *C*). The agency which induced sterility in this case is probably some physiological disturbance which influenced the growth of young pollen grains.

No effect of high temperature on the prophase of meiosis of the pollen mother cells is shown by the data of Lot *B*. The sterility observed in this lot is very low in comparison with Lot *A*, while it is practically equal to that of Lot *b* of the control. No. 15, however, is an exceptional flower which shows comparatively high sterility in Lot *B*. It might be the flower to be marked as Lot *A* since it was the oldest flower of Lot *B*.

In Lot *A*, the percentage of sterility observed in different anthers varies largely. In extreme, it varies from 18.4 to 99.4%, even in the same flower (No. 8). This variation is probably due to the difference in the stage of meiosis which took place in each anther during the time of exposure, because the stage of meiosis in different anthers of the same flower varies in such a way as, from prophase to diakinesis, or from diakinesis to the second meiosis, etc..

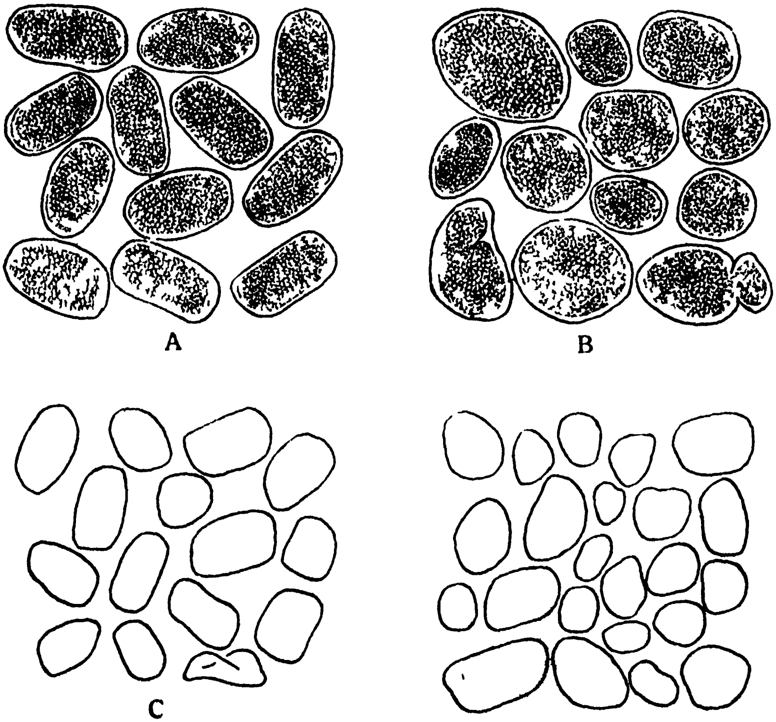


Fig. 3.

Pollen grains. A, normal pollen grains; B, deformed, viable pollen grains; C, sterile pollen grains observed in the control; D, sterile pollen grains observed in the plant exposed to high temperature.

The pollen grains in the flowers of low sterility are generally uniform in shape and size. They take the typical shape of the balsam pollen grains, i. e. semielliptic as shown in Fig. 3, A and Pl. IV [I], 3. On the contrary, the viable pollen grains in the flowers of high sterility vary largely in shape and size as shown in Fig. 3, *B* and Pl. IV [I], 4. In this case, semiglobose pollens are formed very frequently, and necked, oblong pollen grains appear occasionally. The latter is probably due to the imperfectness of cytokinesis. The variation of size is so marked that the largest one reaches to about twice as large as the normal size, while the smallest does not reach to one half of the normal size. The viable pollen grains, both normal and deformed, were placed on agar-sugar medium (distillate water 100, agar 1, sugar 1) for 2 hours at the room temperature of 24°C.. The majority of the pollen grains of both types germinated well, developing long pollen tubes as shown in Pl. IV [I], 6-7. This seems to indicate that the deformed pollen grains function as well as the normal ones.

VIII. THE EFFECT OF HIGH TEMPERATURE ON THE FORMATION OF SEEDS

Three plants of Strain 1 were used as the experimental materials. Two of them, denoted as No. 1 and 2, were exposed to the temperature of 34.5°-36°C. in the thermostat every day between Oct. 11th and 20th. of 1933 with the exception of 15th. and 17th. when the treatment was not made. The other plant used as the control, was placed in the laboratory during the same period that the former ones were kept in the thermostat. Before and after the treatment all the plant materials were placed in the glass house, and they were isolated in insect-proof cages to avoid cross pollination.

During the exposure, the temperature of the glass house varied from 18°C. to 30°C., and that of the laboratory from 18°C. to 20°C.. Judging from their size, all the flower buds of the exposed materials were divided into the following two lots.

Lot *A*, consisting of the flower buds that finished meiosis of pollen mother cells during the days of exposure.

Lot *B*, consisting of the flower buds, the meiosis of pollen mother cells of which were in prophase during the days of exposure.

When the flowers developed mature capsules, the fertility of seeds in each capsule was examined. The result is summerized in table X.

TABLE X.

FERTILITY OF SEEDS IN THE PLANTS REPEATEDLY EXPOSED TO HIGH TEMPERATURE OF 34.5°-36° C.

Lot	Plant	Total number of capsules	Total number of fertile seeds	Number of fertile seeds per capsule
A	No. 1	9	19	2.1
	No. 2	11	0	0
B	No. 1	21	147	7.0
	No. 2	13	91	7.0
Control	No. 3	26	182	7.0

Lot *A* indicates that the fertility of seeds is markedly reduced by exposing the flowers to high temperature when their pollen mother cells are carrying on the first, or the later meiotic division. On the contrary, Lot *B* shows high fertility as good as the control, indicating no effect of high temperature on the prophase of meiosis. The low fertility in lot *A* is undoubtedly induced by the occurrence of abnormal meiosis followed by the formation of non-functional pollen grains.

IX. CHANGE OF PHYSIOLOGICAL CONDITION OF THE BALSAM PLANT AND ITS RELATION TO THE UNSTABILITY OT MEIOSIS

In order to confirm whether the unstability of meiotic division of the balsam is related to the temporary change of physiological conditions of the plant body or not, the following tests were made.

Experiment I. July 26th., 1932.

Four branches were removed from a single plant at 9.30 A. M., and every two of them were put into an Erneman's flask filled with distillate water, so as to draw up water from the cut end. One flask was brought into the glass house, and the other was in the corridor of the laboratory from 10 A. M. to 4 P. M., and then the meiotic division of these materials was examined. The results are shown in Table XI.

TABLE XI.

THE EFFECT OF DIFFERENT TEMPERATURE ON THE MEIOSIS OF THE POLLEN MOTHER CELLS OF THE CUT BRANCHES FROM THE SAME PLANT.

	Temperature (C)	Stage of meiotic division	Nos. of normal figures	Nos. of abnormal figures	Percentage of abnormal figures
					%
Glass house	32–34	I. meta.	95	41	30.1
Corridor	30–30	I. meta.	178	15	7.8

Although the temperature difference was about 2°–4° C., cut branches obtained from the same plant showed the marked difference of about 20% in the abnormality of meiotic division.

Experiment 2. July 22nd-23rd.

Several branches removed from a single plant were put in an Erneman's flask filled with distillate water, just as in the preceding experiment.

They were set in the corridor with their mother plant at 9.30 A. M., July 22nd.. At 4.30 P. M., next day, the mode of meiotic division of the pollen mother cells of both cut branches and their mother plant was examined.

TABLE XII.

MEIOSIS OBSERVED FROM THE CUT BRANCHES AND FROM THE MOTHER PLANT.

	Temperature (C)	Meiotic stage observed	Number of meiotic figures	
			Normal	Abnormal
Cut branches	27–30	I. II.	114	0
Mother plant	27–30	I. II.	122	2

No irregularity was found in both materials as shown in Table XII.

The result of Experiment 1 and 2 shows that it is impossible to induce abnormal meiosis in cut branches without applying high temperature.

Experiment 3. Oct. 2nd-3rd.

One plant was used as the material. At 2 P.M., Oct. 2nd., all leaves on the main stem and those on three branches at the upper part of the plant were cut off, leaving petioles only. The remaining four branches at the lower part were left without defoliating, for the purpose of control.

The mode of formation of pollen tetrad and meiotic division were examined next morning. If quantity of preserved chemical materials has some relationship with the regularity of meiosis, we can expect that the branches, from which the leaves were removed, must show a different result from leafy branches, as preserved chemical materials are assumed to be different in quantity. This expectation was, however, not necessary, since no occurrence of abnormal meiosis was found in either defoliated or leafy branches as shown in Table XIII.

TABLE XIII.

MEIOTIC FIGURES AND POLLEN TETRADS IN DEFOLIATED AND LEAFY BRANCHES.

Meiotic stage	Defoliated branches		Leafy branches	
	Normal	Abnormal	Normal	Abnormal
I division	140	0	150	0
Tetrad	230	0	239	1

Experiment 4. Oct. 4th.-5th.

Six experimental materials planted in earthen pots were divided into three lots, consisting of two plants each. At 10 A.M., Oct. 4th,. all plants were taken into the corridor of the laboratory and watered sufficiently at this time. Each lot was then treated in different ways till next morning. The first lot (excessive water supply) was always placed upon a large glass plate filled with water, in order to draw up water from the bottom hole and to keep the soil in a saturated or nearly saturated condition. The second lot (Normal water supply) was watered once at 5 P. M., Oct. 4th, while the third (Non-watered) was not watered at all.

The auther examined the meiotic division of the pollen mother cells in these lots at 10. A. M., Oct. 5th.. The plants of the first lot, were turgid as the surface of the soil was wet enough to supply a maximum amount of water. In the second lot, the surface of the soil was fairly dry, and the plants seemed to show want of water. In the third lot, the surface of the soil was quite dry, and the upper part of the branches and the main stem was nodding, showing the plant were suffering from the lack of water. The abnormal meiotic figures observed in each lot are compared in Table XIV.

TABLE XIV.

MEIOTIC FIGURES OBSERVED IN PLANTS TREATED WITH DIFFERENT WATER SUPPLY.

Observation / Lots	The stage of meiosis	Number of meiotic figures	
		Normal	Abnormal
Excessive water supply	I	93	0
Normal water supply	I	85	0
No water supply	II	104	3

This table shows that either the water saturation or draught of soil does not affect the regularity of meiosis, as high temperature does.

X. THE EFFECT OF TEMPERATURE ON THE FORMATION OF THE POLLEN TETRADS IN DIFFERENT STRAINS OF BALSAM PLANT

Whereas the strain used as the materials in the preceding studies produced frequently imperfect pollen grains, the author noticed the existence of another strain of balsam plant which always formed perfect pollen grains throughout the same season. For the purpose of testing the effect of high temperature on the meiosis of the latter strain, one plant was placed in the thermostat for 5 hours at 35° C.. Another plant was also tested in the same way, but no irregularity was found in either case. This shows that a certain strain of the balsam plant is not affected by the critical temperature by which other strains are affected.

Further study was made with three strains, representing different horticultural forms to accumurate more data of this problem. These varieties are denoted as Strain 1, Strain 2, and Strain 3, respectively. Strain 1 is the variety used as the materials in the experiments reported in this paper. Botanical descriptions of this variety are given also in the previous paper.(41) Strain 2 is the variety mentioned above, and it is characterized by dark green foliage and single purple flowers variegated with white color. Strain 3 is used for the first time in this study. This variety has a red stem and branches with yellowish, green leaves of small size, and it bears single flewers of red color. Under the outdoor condition just before the commencement of the experiment, Strain 2 and 3 proved to show a normal mode of tetrad formation.

In the experiment, every four plants of each strain were used as materials. These materials were taken together into the glass house from outdoors on May 1st., and the examination was started from May 9th. and ended on May 30th., 1932. The occurrence of abnormality was enumerated out of about 200 pollen tetrads every day, and the results were compared with each other. Table XV shows the summary of this observation.

Distinct abnormalities were found in Strain 1, following the days when the maximum temperature arose higher than 33.0° C, and in extreme cases, the percentage of abnormal pollen tetrads reached as high as 83.7-99%. Strain 3 is less sensitive to high temperature, and the occurrence of high percentage of abnormalities such as 10.3-49.5%, following always on the days of high temperature which attained 35° C.

TABLE XV.

THE COMPARISON OF THE OCCURRENCE OF ABNORMAL POLLEN TETRADS IN THREE DIFFERENT STRAINS OF BALSAM PLANTS.

Date of observation (May)	Maximum temperature of one day before the day of observation (C)	The occurrence of abnormal pollen tetrad in percentage		
		Strain 1	Strain 2	Strain 3
		%	%	%
9	29.5	0	0	0
10	28.5	0	0	0
13	34.0	6.8	-	0.5
15	33.5	14.5	2.9	0.5
16	35 5	—	1.5	2.0
18	35.0	83.4	1.5	49.5
20	35.5	68.7	2.9	16.7
21	35.5	-		10.3
26	35.0	99.0	1.0	2.0
28	35.0	97.6	1.0	20.4
29	31.0	-	0	4.0
30	33.0	31.8	0	-

or higher. Strain 2 proved to be almost insensitive to the high temperature within the limitation of the present study.

These data show that the meiosis of the pollen mother cells of the different strains vary in accordance with their sensitivity to high air temperature.

XI. A NOTE ON ABERRANT INDIVIDUALS APPEARING IN THE COURSE OF THE EXPERIMENT

Among 172 plants raised in the autumn of 1931 and in the summer of 1932, 3 individuals of aberrant type appeared. One was tricotyledonous and the other two were willow-leaved. The former was characterized by developing three cotyledons at the time of germination. This character was brought forth also in the development of upper leaves, and a new joint of young shoots always developed three leaves around it, at the same node instead of developing two leaves as in normal individuals. Owing to this character, the foliage showed much crowded appearance in comparison with normal ones (Plate VII [IV], 2). When a plant grew to a larger size, the main stem displayed conspicuous fasciation. The other characters are not much different from the normal one. The somatic chromosomes counted in the archesporial cells of the pollen mother cells of this plant were 14, representing the normal number. Its growth seemed to be normal, but, unfortunately, this individual died before they began to open flowers, owing to some accident.

In the course of his eleven year's genetic studies in balsam plants, KANNA(21) obtained only one example of heritable fasciation. This mutant arose sporadically from a white-flowered F_3 plant of a cross. Its characters resemble very much the aberrant type found in the author's case, since it developed dichotomic or tricotomic branches in early growth, and flattening of stem occured at the late stage of growth. According to KANNA, F_2 segregation of the cross between the flat and normal stemmed plant showed a ratio of 1:3, indicating that the fasciation is a recessive mutation represented by a single factor. The author's case is also probably due to the same kind of mutation.

The willow-leaved individual occured in 1931, but, it died out soon. A similar individual appeared again in 1932. It grew up and developed flowers. This individual was quite different in many characters from the normal balsam (Plate VII [IV], 3). Owing to the shortening of internodes, dwarf habit was distinct. The height of the plant at the time of full-growth was 21 cm., being about one half of the height of the normal plant. In comparison with normal individuals, the foliage is more sparce, the leaves are extremely narrow, and the flowers are very small and are markedly different in shape and the color. Five stamens occupy the normal position in the flower, but their anthers are white and thin, being deficient of pollen grains. The pistils seemed to be normal in appearance.

Twenty flowers of this plant were pollinated with the normal pollen grains of the sister plant, and the remaining flowers were left for open pollination with the normal plants in the glass house. Slight development of the ovary was observed in one pollinated flower, but it dropped soon. Other flowers also fell down without developing the ovary, showing complete sterility of both male and female organs.

Since the characters of this aberrant type are different in many points from the normal one, we must assume that this individual is a mutant. The mutation characterized by dwarf habit, gametic sterility and willow-leaf form were reported with *Antirrhinum majus* which were treated with ultral violet or Röntgen rays.(60)

XII. CYTOLOGICAL STUDY

In this chapter, the results of the cytological observations which were made in connection with the preceding experimental studies are presented. The materials were gathered from the plants of Strain 1 which had been grown in the glass houses or outdoors. Young flower buds were dipped into Carnoy's solution for several minutes, and then fixed in Navashin's solution for about 24 hours. The usual paraffin method was used and sections were cut in 10–13 microns in thickness. The sections were stained with gentian violet or with Heidenhein's iron alum haematoxilin.

The drawings were made with the aid of a camera lucida, using a Zeiss 1.4 m.m. apochromatic objective 120 and a 15 × conpensation occular. Unless stated otherwise, the drawings were reproduced to give magnification about 2,300 times in diameter.

1. Normal Meiosis

The present author counted 7 bivalents in the pollen mother cells, and also 14 somatic chromosomes in the nucellus of ovary.(43) These agree with the result obtained by other workers in the study of the balsam plant.(21, 40, 54, 62, 68)

During the diakinesis, 7 gemini lie scattered throughout the nuc-

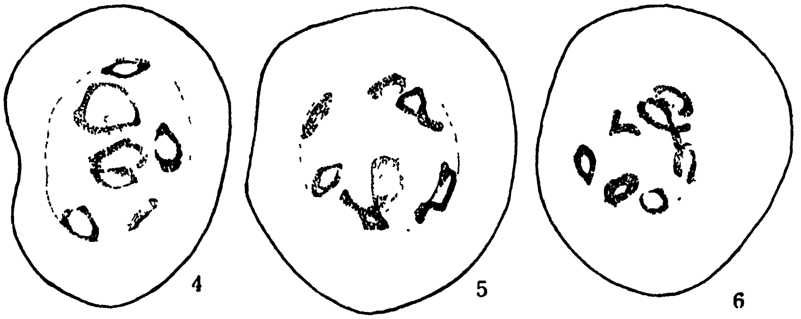


Fig. 4-6.

Normal diakinesis. 4, all the chromosomes take ring shape; 5-6, a few chromosomes display a change of forms instead of taking normal ring shape.

leus. Most of them resume ring shapes consisting of two synaptic members that conjugated each other at both ends (Fig. 4). But, one or two, rarely three of them display a change of forms changing the position at which the synaptic members conjugate. They appear as rings with one or two projections (Figs. 5 and 6).

At the first metaphase, all gemini are regularly arranged on the equatorial plate (Figs. 7-10, Pl. IV [I], 8). Some figures consist of ring shaped chromosomes alone (Fig. 7), while, in others, a few of the chromosomes display the change of form (Figs. 8-9). During the anaphase, the mode of spindle attachment become evident; 5 pairs are subterminal and 2 are median (Fig. 11). As the gemini disjoin and move towards the poles, longitudinal splitting of chromosomes becomes evident, so that some daughter chromosomes appear in the form of double V's or J's giving tetrad chromosomes which are known as a very rare feature of chromosome in the plant kingdom(52) (Fig. 13). In some cases, each chromosome shows a splitting line at the polar view when it is in the first meiosis (Figs. 10 and 12). There is no lagging of chromosomes, disjunction taking place with general unifromity (Figs. 12, 13). Upon reaching the poles, the chromosomes are drawn together, and their individualities become obscure for a short time. Nuclear membranes soon isolate the developing nuclei, and the chromosomes in it are separated by clear space, so that we can distinguish each chromosome at interkinesis (Fig. 14).

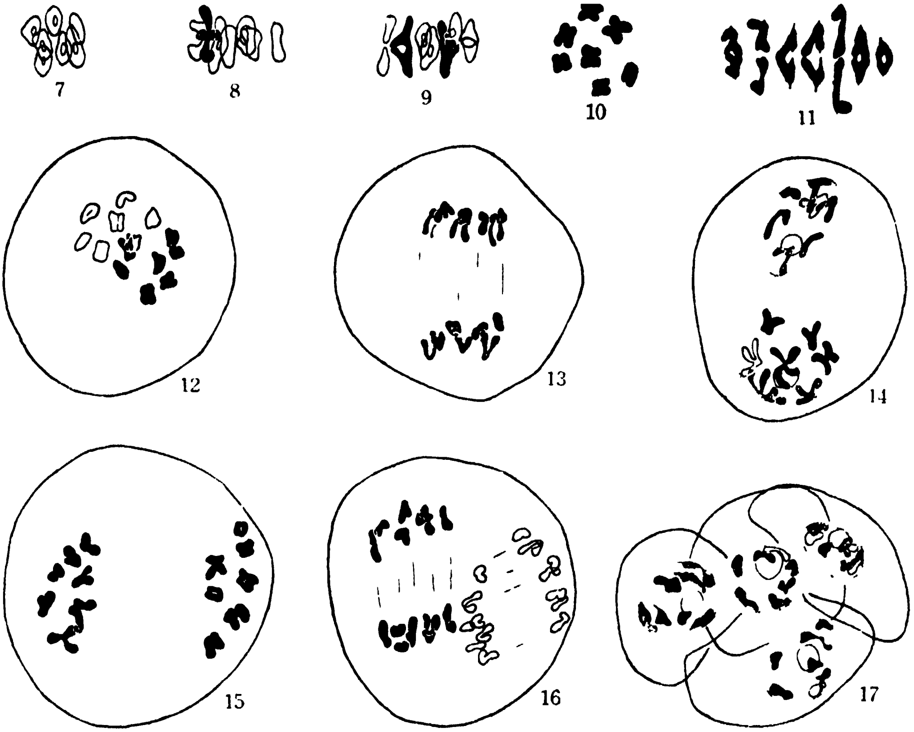


Fig. 7–17.

Normal meiosis. **7,** the first metaphase with 7 ring-shaped bivalents; **8–9,** the chromosomes drawn in solid black display a change of forms at the first metaphase; **10,** polar view of the first metaphase, showing seven gemini; **11,** the early first anaphase, showing the point of spindle attachment in each chromosome, drawn separately (× ca. 3,000); **12–13,** the first anaphase; **14,** interkinesis; **15,** the second metaphase; **16,** the second anaphase; **17,** pollen tetrad with 7 prochromosomes in each microspore. Microspores are drawn slightly apart from each other.

At the second metaphase, 7 chromosomes appear on each equatorial plate (Fig. 12, Pl. IV [I], 9). They split and pass to the poles in the usual manner (Fig. 16), ultimately becoming enclosed within the nuclear membrane. Cell walls are now formed by the furrowing of cytoplasm, and the normal pollen tetrads result. In the nucleus of the microspores, 7 prochromosomes are observed for a short time (Fig. 17), but they soon become reticulate in appearance, developing the typical resting condition.

2. Abnormal Meiosis

Many abnormal behaviors of chromosomes are found. A superficial observation gives us the impression that they are so variable that it might require a long time to interpret and describe them all. But precise examination has shown that, most of the abnormalities are classified into several principal types. In many cases, two or more of these types of abnormality take place at the same time in the same pollen mother cell, so that the behavior of chromosomes appears to be very complicated.

A. Diakinesis

Marked irregularity is observed in the mode of conjugation of synaptic members of gemini. Instead of taking a ring-shape, the synaptic members of gemini conjugate loosely with each other at only one point (Fig. 18), and, in extreme cases, they fail to do so, i. e. non-conjugation takes place (Fig. 19). The synaptic members of such non-conjugating gemini often arrange themselves side by side or nearly so, up to the first metaphase (Figs. 19, 20). From this fact the author

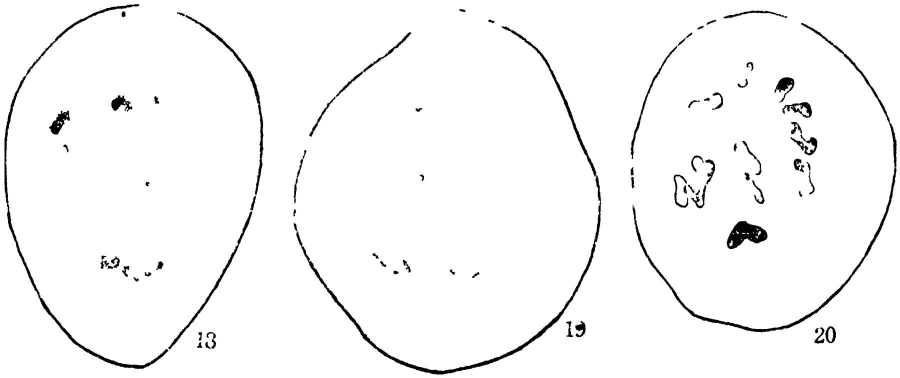


Fig. 18-20.

Abnormal diakinesis and the first metaphase. **18**, diakinesis with 2 ring-shaped chromosomes and five others, the synaptic members of which attach loosely at one end only; **19**, diakinesis with 2 paired and 10 unpaired chromosomes; **20**, the early metaphase with 2 paired and 10 unpaired chromosomes.

assumes that non-conjugation in this case took place after the normal synizesis.

B. Metaphase and Anaphase of the First Meiosis

Lagging of bivalent chromosomes.—At the beginning of the first metaphase, all the gemini lie scattered throughout the spindle, and some of them often lag on the spindle when the others come to the equatorial plate (Fig. 21, Pl. V [II], 10-12). These laggards seem to disjoin at the original place when the other gemini start to disjoin at the equatorial region.

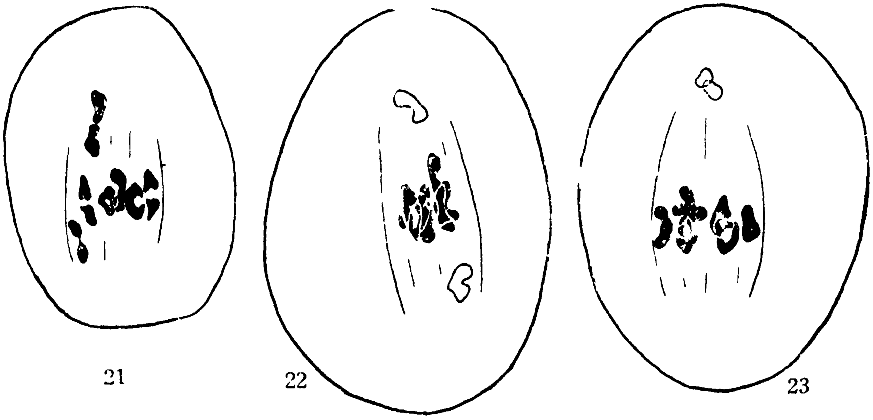
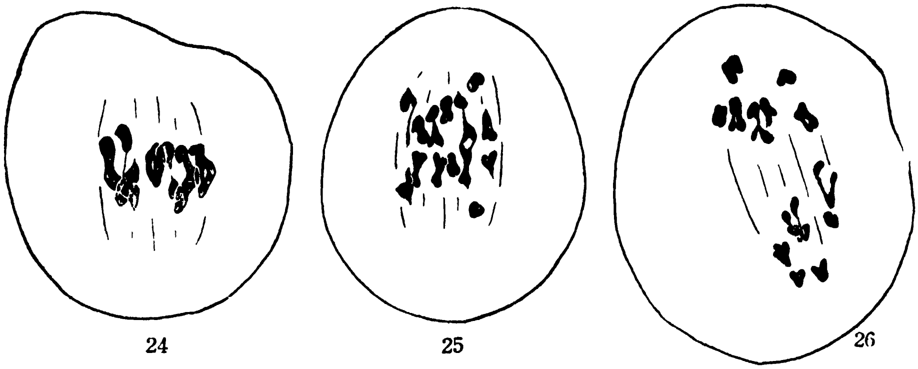


Fig. 21-23.

Abnormal first metaphase. **21**, side view, showing 2 bivalents lagging at the outsides of equatorial plate; **22**, side view, showing 2 bivalents lagging at the region of poles; **23**, side view, showing 2 unpaired chromosomes from a single gemini situated at the region of pole.

Non-disjunction.—Sometimes, a few bivalent chromosomes or a few pairs of non-conjugating chromosomes appear at the region of the poles, when the other chromosomes are staying at the equatorial region. Fig. 22 (Pl. V [II], 13) represents two bivalents which are lagging at the region of the poles. Fig. 23 (Pl. V [II], 14) illustrates two synaptic members of the same gemini which are situated at the region of one pole. These chromosome behaviors must be regarded as non-disjunction, since both synaptic members of such chromosomes may be finally included in the same daughter nuclei.

Random disjunction of bivalent chromosomes.—The typical case is that 7 gemini arranged on the equatorial plate start to disjoin at random (Fig. 24), and they move toward both poles very irregularly as shown in Figs. 25 (Pl. V [II], 15) and 26. As the result of such division, a few chromosomes often fail to pass the poles.



24 25 26

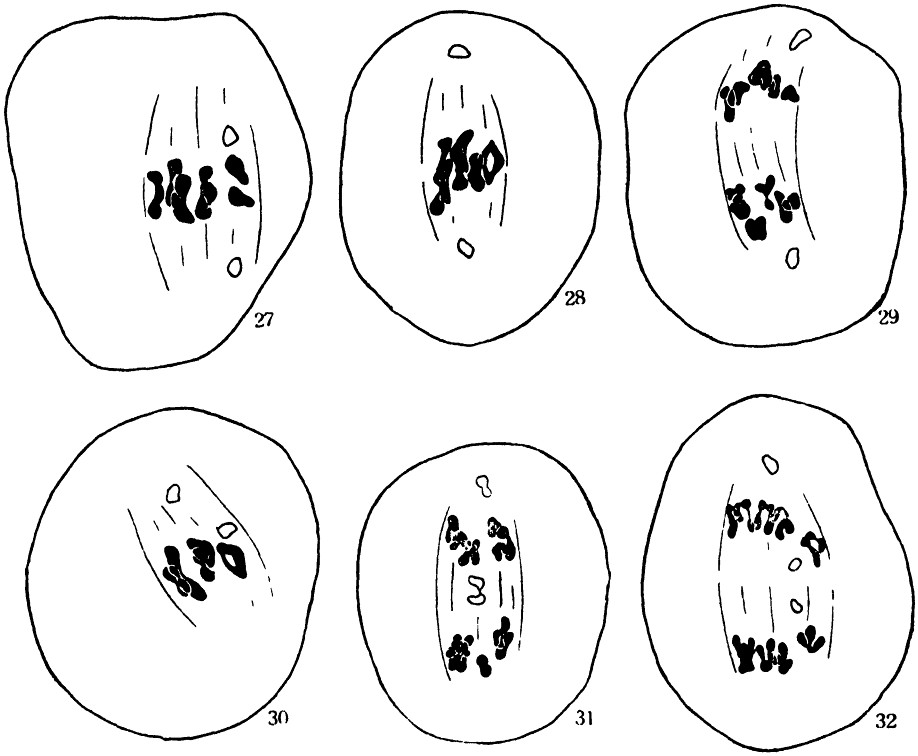
Fig. 24-26.

The first anaphase, showing random disjunction of chromosomes.

Precocious disjunction.—This type of irregularity is one of the modifications of random disjunction of bivalent chromosomes. Some chromosomes disjoin before metaphase that the others are still staying at the equatorial region.

In some cases, the synaptic members of such disjoined chromosomes reach to the poles before the others start to disjoin (Fig. 28, Pl. V [II], 16). Similar behavior of chromosomes was reported by ICHIJIMA(20) with a certain species of *Fragaria*. But, irregularity in his case is due to the hereditary character of the certain chromosome.

When precocious disjunction occurres in a chromosome staying at the equatorial region (Fig. 27), the synaptic members of this chromosome move ahead towards the poles and the other chromosomes follow them (Fig. 29). The phenomenon is very strange, but the result is not much different from the normal division, since the daughter nuclei resulting from this division must recieve a whole set of chromosomes.



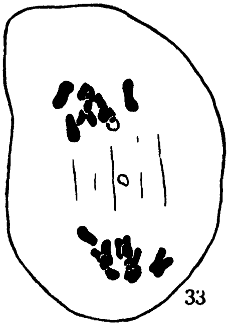


Fig. 27-33.

Precocious disjunction. 27-28, the first metaphase, showing that one chromosome separated at the equator, synaptic members of which are moving towards the poles; 29, the chromosomes disjoined precociously passed the poles and the rests are separating regularly; 30, the first metaphase, showing one gemini disjoined precociously at the outside of the equator; 31-32, the first anaphase, showing that one of the synaptic members of a chromosome disjoined precociously, as in Fig. 30, passed a pole, while the other lagged and splitted at the equator; 33, one of the half chromosomes brought about as in the same way given in Fig. 32, succeeded to pass a pole, while the other is left behind as a laggard.

When the precocious disjunction occurs in the chromosomes lagging at the outside of the equatorial plate (Fig. 30), one of the synaptic members moves towards a pole and the another lags at the equatorial region (Fig. 31, Pl. V [II], 17). The latter splits lengthwise in the late anaphase when the other chromosomes are passing the poles (Fig. 32). And, in some cases, one of the resultant half chromosomes succeeds to pass a pole, while another fails to do so, lagging on the spindle till late (Fig. 33).

Non-conjugation.—The figures of the first methaphase with both bivalent and univalent chromosomes are often observed (Fig. 34-35, Pl. V [II], 18). The number of univalents varies from 2 to 14, corresponding to the number of the rest of bivalents. There are variations in the behavior of the non-conjugating chromosomes ensuing meiosis. When both univalents and bivalents appear in the first metaphase, the former lag around the equatorial region, while the latter arrange themselves regularly on the equatorial plate (Fig. 35). In

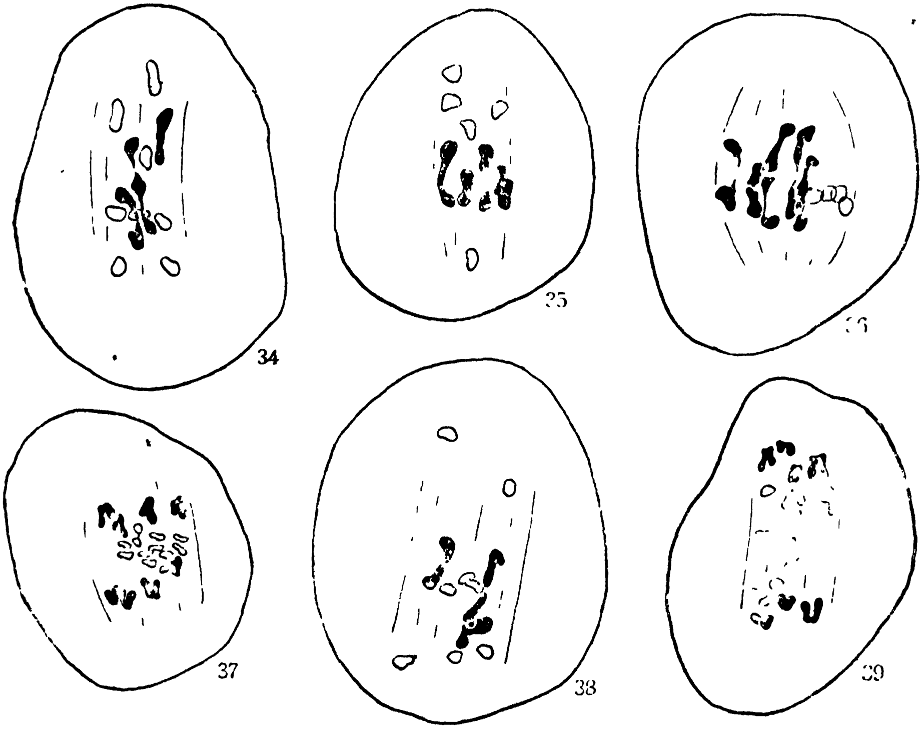


Fig. 34-89.

Non-conjugation. **34**, the early first metaphase, showing that the bivalents are coming to the equator, while the univalents lie scattered throughout the spindle; **35**, the first metaphase, showing that bivalents are arranged on the equatorial plate and the univalents are moving towards the equator; **36**, the early first anaphase, showing that the bivalents began to disjoin, while the univalents lie on the equator; **37**, the first anaphase, showing that the univalents began to split, while the other chromosomes are separating regularly towards the poles; **38**, most of the univalents' lie scattered throughout the spindle, while the bivalents began to disjoin at the equator; **39**, the first anaphase, showing the univalent chromosomes splitted at random, in situ.

anaphase, when the bivalents disjoin and are passing to the poles, the univalents come to the equatorial plate (Fig. 36), and then they split lengthwise, ultimately moving towards the poles following the disjoined chromosomes (Fig. 37). The behavior of univalent chromosomes in this case resembles very much that observed by Kihara(24) in F_1 hybrid between Emmer and Vulgare types of *Triticum*. In some cases, the univalent chromosomes do not come to the equatorial region. They lie irregularly throughout the spindle, when the bivalents start to disjoin at the region of the equatorial plate (Fig. 38), Later, they split lengthwise without coming to the equator, and move toward the poles irregularly (Fig. 39, Pl. V [II], 19).

Non-reduction. The most interesting phenomenon is the so-called

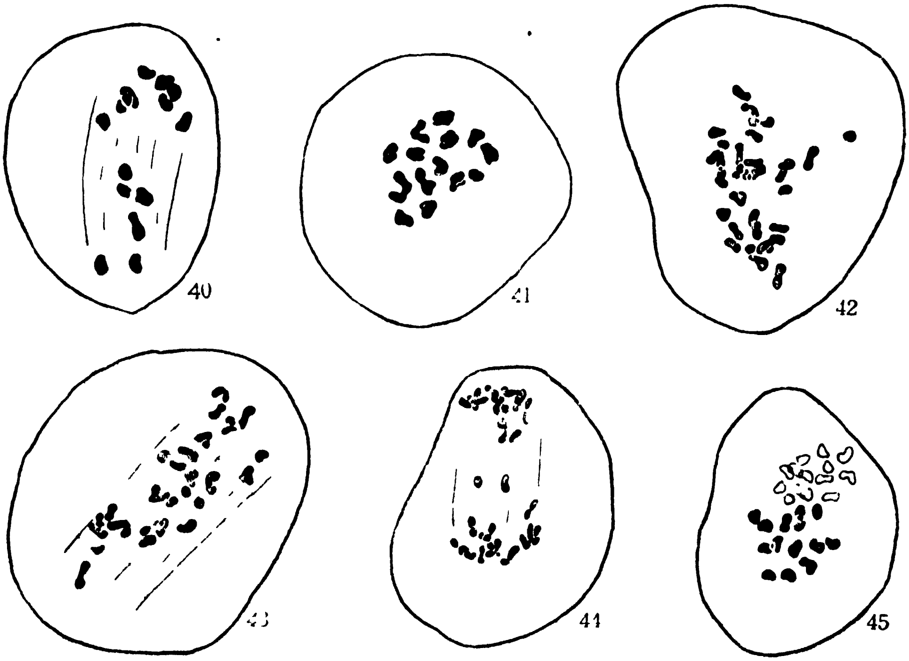


Fig. 40-45.

Non-reduction. **40,** 14 unpaired chromosomes lie scattered throughout the spindle; **41,** a giant equatorial plate comprising of 14 unpaired chromosomes; **42,** An anaphase, showing that all the unpaired chromosomes splitted at the equator and the resultant half chromosomes are spreading into the cytoplasm; **43,** an anaphase, showing all the unpaired chromosomes separating irregularly along the axis of one giant spindle; **44,** an anaphase, showing that all the unpaired chromosomes separating almost regularly along the axis of one giant spindle; **45,** polar view as in Fig. 41, showing every 14 chromosomes at each pole.

non-reduction. All chromosomes apper as univalent, and they lie scattered throughout the spindle at the first metaphase (Fig. 40). Then, they arrange themselves in the usual manner forming a giant equatorial plate (Fig. 41, Pl. V [II], 20-21), or sometimes in the faw as shown in the previous paper.(41) In most of the cases, they split and move towards the poles very irregularly (Fig. 43, Pl. VI [III], 23), or they split at the equator, spreading finally into the cytoplsam without coming to the poles (Fig. 42, Pl. VI [III], 22). But, there are a few cases where all the univalent chromosomes split regularly, giving ultimately 14 chromosomes to each pole (Fig. 44-45). Fig. 46 shows a very rare phenomenon that 14 univalent chromosomes are scattered throughout the cytoplasm. This is probably due to the failure of the formation of spindle.

Standing of chromosomes out of the spindle.—One finds rarely a few chromosomes which stand in cytoplasm out of the spindle (Fig. 47). If such chromosomes are bivalent, they seem to disjoin during the anaphase (Fig. 48.).

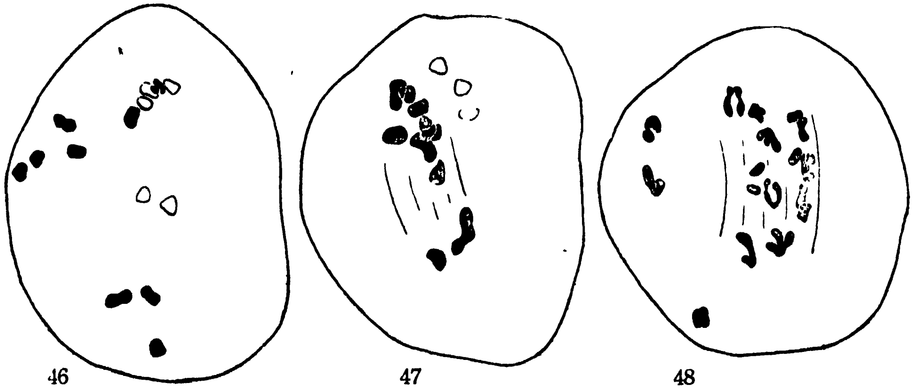


Fig. 46-48.

Abnormal first meiosis. 46, 14 unpaired chromosomes scattered throughout the cytoplasm; 47-48, the early metaphase and anaphase, with a few chromosomes wandering in the cytoplasm.

Fragmentation.—Among all the preparations examined in the present study, only three cases of fragmentation which took place during the first meiosis were found. Fig. 49 (Pl. VI [III], 24) shows that fragmentation took place in one daughter chromosome at the point of the spindle fiber attachment. The proximal part of this chromosome is passing to one pole, while the distal part is left at the region of the equatorial plate. In Fig. 51, we find one fractured chromosome, the proximal part of which is passing to one pole with the other chromosomes, while the distal part attaches to the distal part of its synaptic member, which is lagging at the equatorial region· The former segment of chromosomes represents the phenomenon of deficiency, and the latter is smilar to the phenomenon of duplication. A similar example is also given in Fig. 50, in which we found two fractured chromosomes.

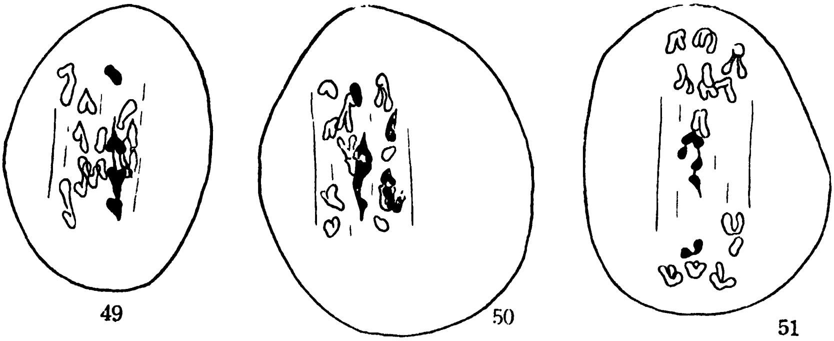


Fig. 49–51.

Fragmentation in the first meiosis. **49**, an anaphase with one fractured chromosomes; **50**, an anaphase with 2 fractured chromosomes; **51**, an anaphase with one fractured chromosome.

C. Interkinesis

All chromosomes are included in two daughter unclei, but their behavior is abnormal. - Fig. 52 (Pl. VI [III], 25) shows unequal distribution of chromosomes. We count 9 chromosomes in one nucleus, while only 5 in the other. Fig. 53 shows two nuclei that have chromosomes of equal number, but they include 6 single and 2 half chromosomes. In Fig. 54, 5 single and 3 half chromosomes are observed in one nucleus, while 4 single and 7 half chromosomes in the other.

Detachment.—There are found often a few single or half chromosomes that were extruded out of the nucleus. Such chromosomes stand solitary in the cytoplasm, showing their independent individuality. Fig. 55 shows one half chromosome that is wandering in the cytoplasm. Its synaptic member is found in the nucleus shown at the right hand side. Fig. 56 shows two half chromosomes extruded out of the nuclei. The synaptic member of one of them is included in the nucleus shown at the left hand side.

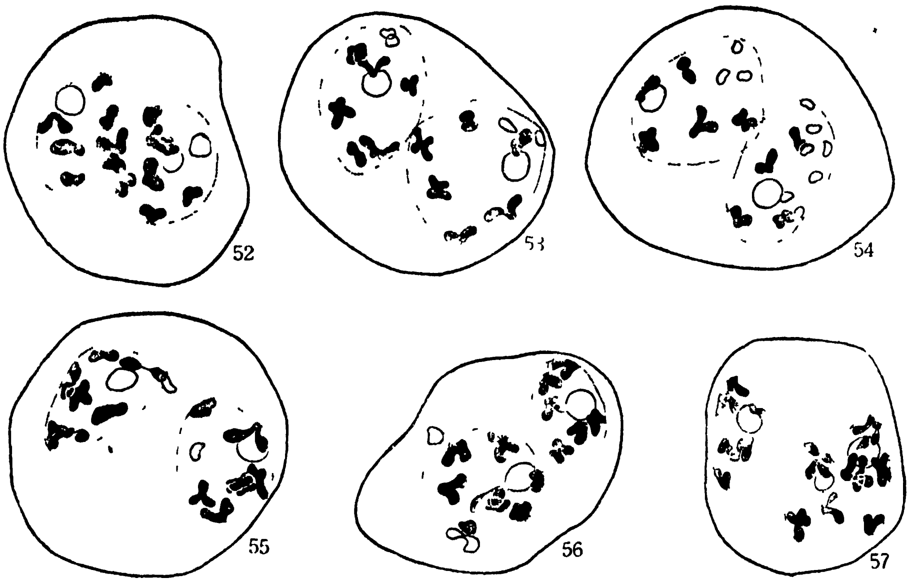


Fig. 52-57.

Abnormal interkinesis. **52**, in both daughter nuclei, 5 and 9 univalents are counted, respectively; **53**, 6 univalents and 2 half chromosomes are observed in each nucleus; **54**, one daughter nucleus, comprising of 5 univalents and 3 half chromosomes, and the other with 4 univalents and 7 half chromosomes; **55**, the half chromosome drawn in white, which is extruded out of the daughter nuclei; **56**, 2 chromosomes drawn in white, extruded out of the daughter nuclei; **57**, interkinese with an extra nucleus.

Formation of extra nuclei. In some cases, the chromosomes which failed to pass the poles at the first meiosis, are included into small, extra nuclei (Fig. 57). Such nuclei seem to be formed when two or more extruded chromosomes become closely clumped together, since they have always two or more chromosomes.

D. The Second Meiosis

Metaphase with extra chromosomes.--It is not a rare occurrence that more than 14 chromosome units are counted at the second metaphase. The occurrence of extra chromosomes in this case is probably due to the splitting of single chromosomes that, sometimes, takes place abnormally at the first meiosis. Fig. 58 (Pl, VI [III], 26) shows the equatorial plates of the second metaphase that have 21 chromosomes in total. These chromosomes must consist of 7 single and 14 half chromosomes.

Wandering of chromosomes in cytoplasm.—Frequently, a few chromosomes fail to be included in the daughter nuclei at the end of first meiosis. They wander in cytoplasm at the second metaphase when the other chromosomes are arranged on the equatorial plate. Fig. 59 shows 2 single chromosomes that are wandering in cytoplasm, and Fig. 60 illustrates 2 half chromosomes that stand in cytoplasm. A similar example is also given in plate VI [III], 27.

Lagging of chromosomes at metaphase.– Frequently, all the chromosomes lie scattered throughout the spindles at the beginning of metaphase (Fig. 61). These chromosomes move very irregularly towards the equator, and most of them seem to succeed to reach there, but a few of them are often left behind as laggards (Fig. 62, Pl. VI [III], 28). In some cases, the laggards are observed at the region of poles as shown in the spindle at the right hand side of Fig. 63 (Pl. VI [III], 29). In this figure, 1 single chromosome is situated at the pole, while the others are arranged on the equatorial plate· This chromosome seems to lag at the same place till late anaphase, being ultimatety included in one of the resultant nuclei. If the other chromosomes split regularly, the resaltant two nuclei will have 6 and 8 chromosome, respectively.

Union of both equatorial plates.—One finds sometimes that both equatorial plates of the second metaphase appear very closely on the same level. Examples are shown in Figs. 64 (Pl. VI [III], 30) and 65. In the former figure, both equatorial plates are arranged side by side, very closely as if they united into a large equatorial plate. In the

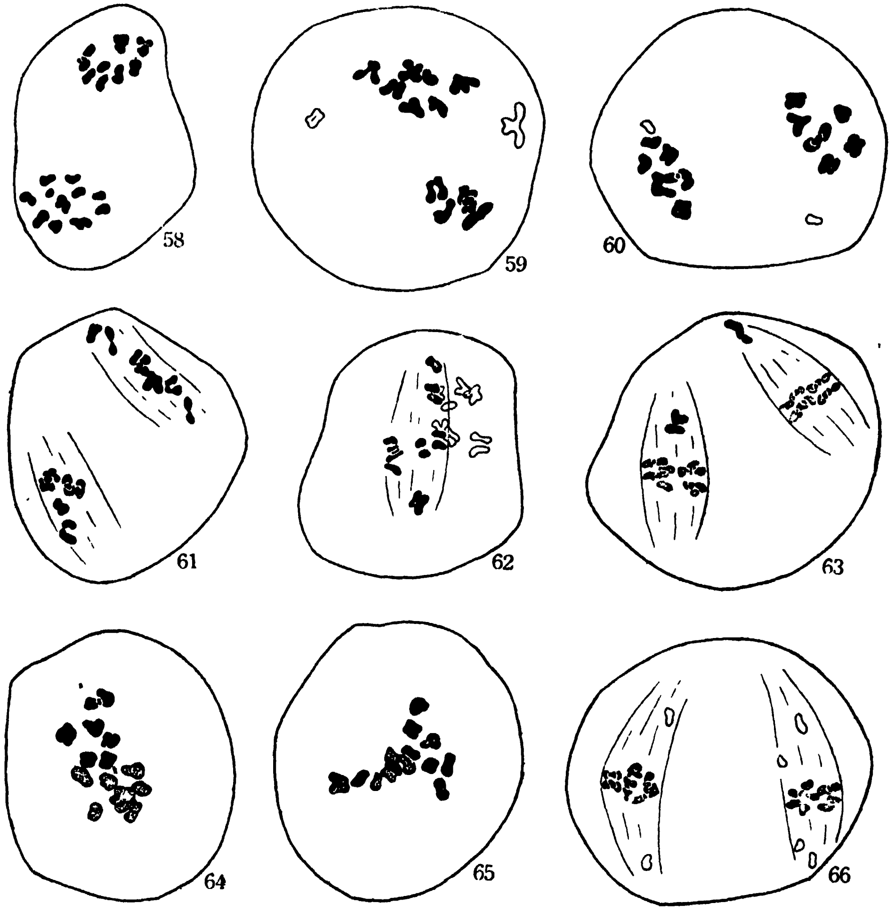


Fig. 58–66.

Abnormal second meiois. **58**, metaphase plates consisting of univalent and half chromosomes; **59**, metaphase, showing 2 univalents wandering in the cytoplasm; **60**, metaphase showing 2 half chromosomes wandering in the cytoplasm; **61–62**, metaphase with lagging chromosomes; **63**, metaphase, showing one chromosome situated at the pole; **64–65**, union of both equatorial plates; **66**, metaphase with a few chromosomes splitted precociously.

latter, both equatorial plates are situated near each other vertically, and part of them is brought into contact. These figures must be assumed to show categories of the fusion of both equatorial plates.

Random splitting of chromosomes.—We observe often that a few chromosomes split and move towards the poles, while the other chromosomes are still arranged on the equatorial plate of the second metaphase (Fig. 66, Pl. VI [III], 31). This behavior of chromosomes resembles very much the precocious disjunction observed in the first metaphase.

Fig. 67 and Pl. VI [III], 32 illustrate examples of typical cases of random splitting of chromosomes in the second anaphase. All the chromosomes split at random and they move towards the poles very

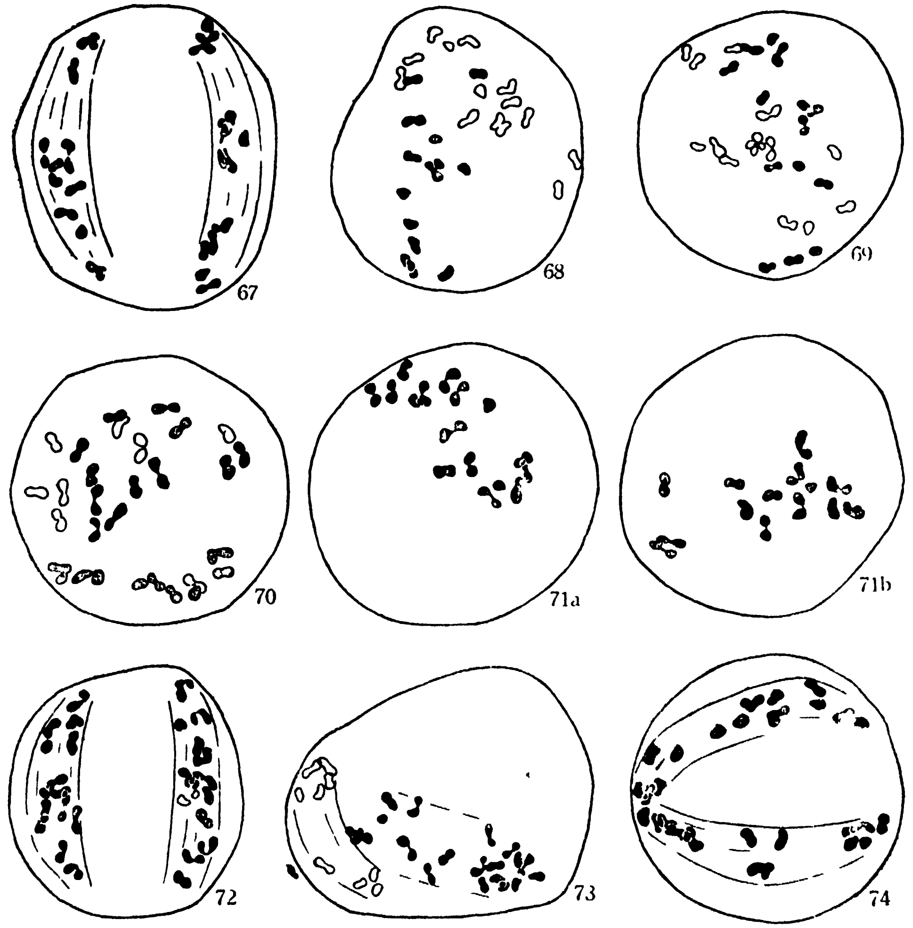


Fig. 67–74.

Abnormal second anaphase. **67**, random separation of all chromosomes; **68–70**, spreading of chromosomes into the cytoplasm; **71, a, b, 30** chromosome units oberved in a single pollen mother cell; **72**, the chromosome drawn in white on the spindle at the right hand side shows a half chromosome which fractured at the point of spindle attachment; **73, 2** spindles situated at unusual positions; **74**, union of poles of different spindles.

irregulary. At telophase, some chromosomes succeed in arriving at the poles, but the others are frequently left behind (Fig. 67). In some cases, the chromosomes split and move towards the poles. very irregularly at the start (Fig. 68). Later, they begin to spread (Fig. 69), and, ultimately, they scatter themselves throughout the cytoplasm (Fig. 70). Such a division is probably due to the weakness of the attracting power of the poles. Fig. 73 shows a very abnormal case of anaphase. All the chromosomes are divided into groups of 19 and 9 to both spindles. The positions occupied by these spindles are unusual, and the division of chromosomes is also very irregular.

Fragmentation.—We find occasionally the anaphase figures that have more than 28 units of chromosomes. A and B of Fig. 71, show all the chromosomes of a single pollen mother cell situated at two different places in the cell. We count here 30 chromosomes instead of 28, the expected number. The appearance of 2 extra chromosomes in this case is probably due to fragmentation of one single chromosome or due to that of 2 half chromosomes. Actual evidence of the case where the single chromosomes fractured has already shown in the study about the first meiosis (Figs. 49-51). Fractuation occurs also in the half chromosomes of the second meiosis. An example is given in Fig. 72. The chromosome drawn in white in this figure is fractured at the point of the constriction.

Union of the poles of different spindles.- Fig. 74 (Pl. VI [III]. 33) illustrates a very rare case that two poles from the different spindles of the second meiosis are brought in contact. About half of the chromosomes on each spindle are moving towards these poles. This phenomenon must be assumed as the union of poles of different spindles. One diploid and two haploid pollen grains may result from this method if all the chromosomes pass to the poles regularly.

Anaphase bridge.—We rarely found the phenomenon called anaphase bridge. Fig. 75 represents this behavior. One chromosome is stretched very long from one pole to another, like a spring pulling from the opposite sides. Such a chromosome seems to separate ultimately as shown in Fig. 76. Two separate, elongated chromosomes observed here, are becoming short to recover their normal size.

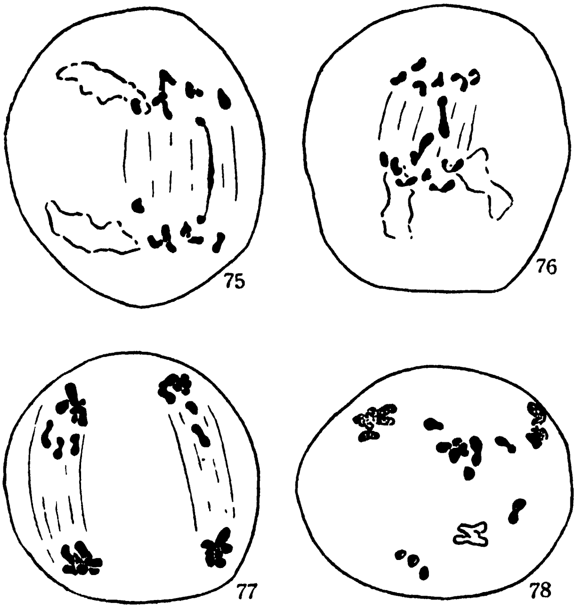


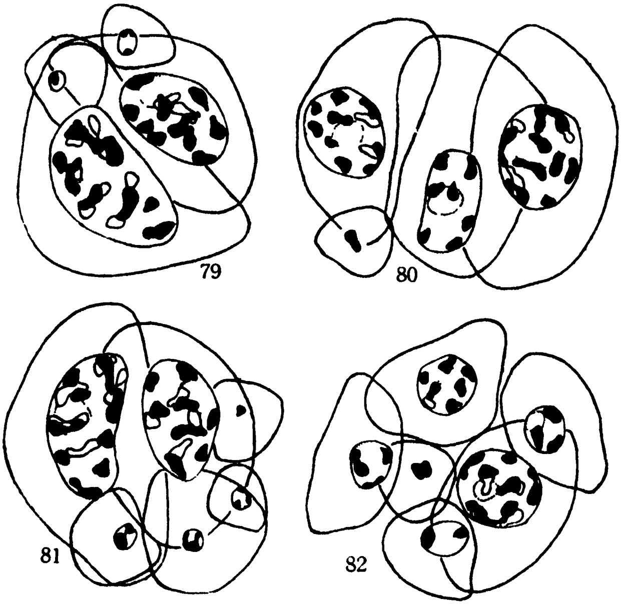
Fig. 75-78.

Abnormal late second anaphase. 75-76, anaphase bridge; 77, telophase with lagging chromosomes; 78, telophase showing the chromosomes gathering at several groups.

Random gathering of chromosomes in the late anaphase.- In usual way, the chromosomes that are scattered throughout the cytoplasm, or separated very irregularly on the spindles are gathered at random into several centers in the late anaphase (Eig. 78), then they become organized into many micronuclei, resulting ultimately in multicellular pollen tetrads.

E. Tetrad Stage

The pollen tetrads resulting from irregular meiosis are very abnormal. The number of microspores counted in these pollen tetrads varies so largely as already shown in Table III. The counting of prochromosomes in each microspore shows also large variation. Several examples are shown in Figs. 79-82. This condition is more clearly illustrated in Table XVI which indicates the frequency of the number



Eig. 79-82.

Abnormal pollen tetrads, showing the variation in the number of prochromosomes found in each micronucleus. Each microspore is drawn slightly apart from each other.

of prochromosomes counted with 100 microsopores out of the pollen tetrads in a single anther.

TABLE XVI.

Frequency of the Number of Prochromosomes in the Microspores of Pollen Tetrads.

Number of chromosome	1-6	7	8-13	14	15-17	Total
Frequency	46	30	21	0	3	100

As the table shows, the number of prochromosomes ranges from 1 to 17, and 70% of the microspores show abnormal number. Among these microspores, the minus chromosome class will generally be non-viable. But the plus chromosome class may survive, and some of them will ultimately give rise to functional pollen grains, if they have a whole set of chromosomes, besides the extra ones.

XIII. DISCUSSION AND CONCLUSION

Among the papers dealing with the effect of high temperature on the meiosis of plant, Stow's(56 57) study in the cultivated potato is the only one which touched the problem of the influence of seasonal high temperature. But, there are different opinions as to the direct effect of temperature on meiosis in this case. Fukuda(11) reported that the unbalance of physiological energy in the plant body is the principal cause that brings about the sterility in the cultivated potatos, and the degree of unbalance in this case is considered by him to be affected more or less by the environmental conditions. Longley and Clark(30) after a study of *Solanum tubersum* and its relatives, concluded that the cultivated potatos with 24 chromosomes in the haploid phase are tetraploids of hybrid origin, and the lack of harmony in the chromosome complement of tetraploid varieties is the major cause of the occurrence of abnormal meiosis. They admitted, however, that there existed a few selective individuals, the meiosis of which is affected by the environmental changes, probably rainfall, though conclusive evidence is lacking. By the examination of secondary association of chromosomes in potatos, Laurence(29) and Müntzing(41) reached a conclusion that 6 must be regarded as the original basic chromosome number of this species. Bleir's(6) opinion is that the disturbance of meiosis in the potato is occasioned by the same agency which brings about sterility and whose action may be influenced by temperature, and the disturbed agency in this case is some physiological condition in the plant. Similar explanation as to the temperature relation was given by Kostoff(27) about the F_1 plants of red pepper in which irregular meiosis increased under the condition with reduced or raised temperature. Studing the stimulant effect of a certain virus disease on the meiotic division of *Nicotiana*, the same author(28) raised the following questions: Was not Bleier's specific a virus? Did not Stow's work with potatoes infected with a certain virus, and the results he obtained were not due to a combination of virus and temperature?

Judging from the results of these experiments, the cultivated potatos seem to be inadequate as the experimental material of this kind for a study aiming to prove the direct effect of air temperature on the meiosis.

The plant materials used in the present study are not of hybrid origin as far as chromosome number is concerned as already reported.(41) And the progeny test also proved that it is a pure diploid strain from the time that the study was commenced. Abnormal high intensity of physiological stimulant or special chemical substances, which are known as injurious to the meiotic division of some plants, seems not to exist under conditions prevailing during the experiments. This shows that the meiotic irregularity in the present study is not due to either hybridity of the plant or extremely severe stimulation. Over-supply of water or extreme draght did not affect the regularity of the meiosis, and also the sudden change of physiological conditions, such as the removal of all leaves, or of roots at the bottom of the plant. Only the air temperature exhibited an intimate relationship with the daily changes of meiotic irregularity.

All experimental studies of the author about the mode of tetrad formation or the behavior of meiotic division, which were carried out in the glass houses, outdoors and the laboratory, agreeded very well in the results. Summarizing the results of the experiments, the author was able to determine the critical point of temperature which disturbs the meiotic division of Strain 1, about 30° C., though slight difference might happen due to the physiological conditions of the plant. According to the observation on the tetrad formation and the meiotic division in the glass houses or outdoors, irregular meiosis occurs when the maximum day temperature arises to a degree higher than about 32° C.. The number of abnormal meiotic figures also increases and the degree of irregularity becomes more extreme, in a way closely parallel to the rise of temperature. In any time when the maximum day temperature falls below 30° C., the pollen mother cells recover their power performing normal meiosis. Similar results were also obtained in a study carried out under artificially controlled temperature. In this case, the positive effect of thermostat temperature on the meiosis was distinct at 31-32° C. or higher (for 5 hours), while it was slight at 29-30° C., and no effect at 28° C. or lower.

The stages of meiosis which seem to be most sensitive to high temperature must be about diakinesis and the later stages. The following observation supplies an evidence for this assumption: (1) Non-paired chromosomes appear in abnormal diakinesis, but the synaptic members in this case are often arranged side by side showing that they were in conjugation shortly before this stage. (2) The distinct irregularity was directly observed in the diakinesis and the later stages. (3) The prophase of meiosis exposed to high temperature was followed by the formation of normal fertile pollen grains and seeds, while the later stages of meiosis which were treated in the same way were followed by the formation of pollen grains and seeds of high sterility.

A similar suggestion was made by MICHAELIS(33) with *Epilobium* treated with low temperature, and an analogous phenomenon was also reported by TAKAGI(61) with *Lichnis* influenced by high temperature.

It is very interesting to note that the meiosis of different strains of balsam plants are not similarly affected by the equal degree of high temperature. In the present study, Strain 1 was affected by the maximum day temperature of 32° C. or higher, Strain 3 by the maximum day temperature of 35° C. or higher, while Strain 2 was not affected apparently at 35° C.. A similar phenomenon is reported by HEILBORN.(14) with apples. He used the number of univalent chromosomes as a measure of the influence of the different temperature. According to STOW.(57) the meiosis of the pollen mother cells of potatos is usually sensitive to high temperature, if the plant is susceptible to the mosaic disease.

About the relationship between the temperature and the meiotic division of plants, SAKAMURA and STOW(49) assumed that the meiotic division of plants blooming in autumn must be influenced more easily by high temperature. This seems to mean that the temperature changing suddenly is effective to cause it, but, undoubtedly, a slight rise of air temperature in the summer season also causes the disturbance of the meiotic division of some plants, as is shown in the present study. HEILBORN(14) concluded that the early blooming varieties are more sensitive to high temperature than the late blooming varieties. His experimental data, however, is not big enough to warrant the assumption.

Table XVII summerizes known cases where the meiotic division of plants was disturbed experimentally at certain degree of high temperature. The critical temperatures are also refered to with respect to the blooming season and climatic adaptability of the plants.

TABLE XVII.

THE CRITICAL TEMPERATURE TO THE MEIOSIS OF PLANTS, WITH REFERENCE TO THE BLOOMING SEASON AND THE CLIMATIC ADAPTABILITY OF PLANTS.

Species	Critical temperature (C)	Blooming season	Cliamtic adaptability	Author
Gagea lutea	30	early spring	temperate	SAKAMURA & STOW, 1926
Solanum tuberosum	25.7-39.0	summer	do	STOW, 1927
Lychnis Sieboldii	38.0-39.0	spring	do	TAKAGI, 1928
Triticum vulgare	35	late spring	do	BLEIR, 1928
Malus sylvestris				
Savestaholm	30	spring	do	HEILBORN, 1930
Akero *	25.0-30.0	do	do	do
Astrachan	20.0	do	do	do
Petunia violacea	40.0-47.0	early summer	subtropical	MATSUDA, 1930
Impatiens Balsamina				
Strain 1	30.0	summer	tropical	NAKAMURA
Strain 3	35.0	do	do	do

* The maximum day temperature.

As the table indicates, the critical temperature to each species or variety is not equal, but the disturbance of the meiotic division happens in the most of cases at a temperature higher than 30°C., without limitation of blooming season or the climatic adaptability of plants.

It is noteworthy that many of the abnormal chromosome behaviors observed in the balsam plant represent the cases of abnormality reported by many authors with other plants that were influenced by high or low temperature. For instance, the irregular behavior of chromosomes such as detachment, non-disjunction, non-conjugation, random disjunction, lagging, precocious separation, etc., are caused by the effect of both high and low temperatures.(2, 14, 23, 32, 33, 43, 53, 61) Fragmentation is also induced by the effect of low temperature.(2, 64) This phenomenon seems to show that, in certain limitation, both high and low temperatures affect the pollen mother cells to change the property of protoplasm in the same way so as to cause irregular meiosis of similar kinds.

The survey of literature about the effect of temperature on the protoplasm brings several evidences on the protoplasmic viscosity. According to HEILBRUNN,(16 17) the egg of *Cuminigia* shows the maximum viscosity at about 15°C., while the viscosity of this egg decreases steadily with the rise or fall of temperature, if temperature is higher or lower than 15°C.. The viscosity, however, increases very rapidly giving other maxima, if temperature falls as low as 3°C., or it rises as high as 31°C.. Duration of temperature higher than 31°C. results in coagulation of the protoplasm resulting ultimately in the death of the cell. Heat coagulation in this case is to some degree reversible, if the effect of temperature is not too extreme. Reversible viscosity of proptoplasm as to the effect of low temperature was also reported by WEBER and HOHENEGGER(66) with *Phaseolus.*

These phenomena are conceivable to be parallel with the unstability of meiosis caused by the effect of temperature. The irregular meiosis induced by the effect of both extremes of temperature, high and low, corresponds to the maxima or minima of viscosity of protoplasm brought about by extreme rise and fall of temperature. Meiosis of the plant affected, recovers to normal, if the temperature returns to optimum. This condition resembles the reversible heat coagulation of protoplasm. Furthermore, we have records that the viscosity of protoplasm has an intimate relationship with the cell and nulear division. According to the experimental study of CHAMBERS,(3) high viscosity of protoplasm accelerates cell division, while low viscosity retards it. The periodical changes of protoplasmic viscosity during the nuclear division was also reported by CHAMBER(8) and ZIMMERMAN.(70) KOSTOFF(28) considered that pathological and mechanic disturbance induced by the injuries due to gall, or to tumors, or to wounds, seem to act to change the viscosity of protoplasm and to bring about the occurrence of irregular nuclear divisions. Various kinds of physical and chemical stimuli that are known to affect the nuclear division of plants, also act to change the viscosity of protoplasm. These are ultra violet ray, (17 62) X-ray,(68) radium ray,(68) and narcotics(18) such as ether, chlorophorm and chloralhydrate.

BLEIR(5) pointed out that, in the pollen mother cells of *Triticum vulgare*, a special belt forming a part of cytoplasm, stained dark with reagent, is most sensitive to temperature. When high or low temperature acts upon the wheat plant, this belt is abnormally elongated or clumped, and it invades the spindles, disturbing the polarization of the latter. This is followed by chromosomal abnormality. The existence of similar kinds of belts is also reported by SMITH(54) with *Impatiens pallida.* The phenomenon showed by BLEIR seems to have some relationship with the change of viscosity of protoplasm.

From these facts, the author considers that the irregular meiosis caused by the effect of temperature, must be preceded by abnormal decrease or increase of viscosity of protoplasm which may occur shortly before the death of the pollen mother cells. The change of viscosity in this case will be associated with the unbalance of the energies which control the mechanism of meiosis such as the formation of spindles and the movement of chromosomes.

If these assumptions are admitted, it is reasonable that the critical point, i. e. temperature to the unstability of the meiosis of the pollen mother cells varies according to kinds of plants, because, the factor which governs the sensitibity of meiosis to temperature is neither blooming season nor climatic adaptability of the plants, but it is the heat resistance of protoplasm of the pollen mother cells that must be a characteristic feature for each kind of plant.

In the balsam plant, the disturbance of spindle formation brought about such abnormal behaviors of chromosomes as the scattering of all chromosomes throughout the cytoplasm, and the union of two equatorial plates or poles of different spindle of the second meiosis, as described before. And the other irregularities of chromosome behavior, such as precociousness, or random separation, lagging, fragmentation, non-disjunction, non-conjugation, detachment, etc. may be resulted by the unbalance of the energies which control the movement of each chromosome.

As the result of such irregular meiosis, many, deformed, pollen grains were formed as well as the sterile ones. The deformed pollen grains in this case displayed a marked variation in their size and shape, though they were stained deeply with aceto-carmine solution. Most of these pollen grains germinated well on the media, consisting of agr and sugar, showing that they were viable. A similar case was reported by SAKAMURA and STOW(40) about *Gagea lutea*, treated with high temperature. In the latter case, the size of the pollen grains varied according to the number of chromosomes.

Judging from the behavior of meiosis in the balsam plant, we can expect the occurrence of various kinds of abnormal pollen grains besides normal ones. The former may be classified into the following categories: (1) Diploid pollen grains. (2) Pollen grains with a few extra chromosomes as well as a whole set of chromosomes. (3) Pollen grains with a few chromosomes structurally changed, besides normal ones. (4) Pollen grains with unbalanced chromosome complements. The pollen grains of types 1, 2 and occasionally 3 are viable, since they have one or more whole sets of chromosomes, though they might be unusual in their chromosome number. The deformed, viable pollen grains observed in the present study are probably represented by these types of pollen grain. The pollen grains of type 4 must represent the sterile pollen grains, since the unbalance of the chromosome complements renders the pollen grains less viable.

The irregular meiosis and the pollen sterility of uncertain causes are assumed by many authors as a reliable indication of the hybridity of plant. This may be true in the ordinary cases, but, there is a possibility, in exceptional case, that the meiosis is disturbed by the effect of seasonal air temperature, being followed by partial, or perfect sterility of pollen grains and seeds.

Partial sterility caused by the effect of high air temperature represents an interesting phenomenon from an evolutionary point of view, because the abnormalities of the meiosis of the pollen mother cells often brings about viable pollen grains with unusual chromosome number. If the generative nuclei with an increased number of chromosomes participate in the fertilization process, euploid and aneuploid progenies may rise. Such a probability is very high under the climatic condition of Taihoku where high air temperature is very frequently met with during the growing season of the balsam plant. For instance, the maximum day temperature in Taihoku during the summer season of 1933, ranged from 22.5° C. to 36.4° C., and the maximum temperature higher than 32° C. was counted 59 times. Under this condition, the balsam plant in question thrived vigorously. Similar conditions may be repeated from year to year, and we can expect high unstability of meiosis of the susceptible strain of the balsam plant. Similar phenomenon was suggested by HAGEROUP(12) to interplet the origin of certain, poliploid plants grown at Timbusku in West Africa. He did not show, however, precise experimental data to prove the direct effect of high air temperature upon the meiosis.

The foregoing discussions lead the author to a conclusion that the seasonal high air temperature of the tropical and subtropical regions is conceivable to play an important rôle in the occurrence of chromosomal mutation in some plants. There remains, however, the following questions. Does high air temperature affect also the meiosis of the ovocyte? What kinds of aberrant may rise among the progenies of the balsam plant in question? Studies on this line are now being conducted by the author to obtain more conclusive data that will support the present conclusion.

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Summary

(1) The principal object of the present study is to prove that high air temperature within the range of normal seasonal fluctuation, gives an influence upon the regularity of meiosis of the pollen mother cells of a certain strain of the balsam plant (Strain 1) to cause frequent irregular meiosis followed by high sterility of pollen grains and seeds.

(2) The plant materials, placed both in a glass house and outdoors, showed unstability of meiosis, the degree of which varied day by day. In any time, the meiosis was abnormal when the maximum day temperature attained to above 32°C., while it was normal when the maximum day temperature fell down below 30°C..

(3) The laboratory experiment carried out with different controlled temperatures proved that the temperature of about 30°C. continued for 5 hours afforded the critical point which induces irregular meiosis in the present material.

(4) Corresponding with the rise of temperature, the number of the pollen mother cells affected markedly increased, and the degree of irregularity of meiosis became more extreme.

(5) The prophase of meiosis of the pollen mother cells was not so sensitive to high temperature. while the later stages of meiosis was highly sensitive.

(6) The abnormal behaviors of meiosis vary largely, are described in Chapter XII. They represent nearly all cases of abnormality reported hitherto with other plants.

(7) Irregular meiosis was followed by the formation of abnormal pollen tetrads, and of viable or sterile pollen grain with unusual chromosome numbers. And it was also followed by the high sterility of seeds.

(8) Sudden change of certain physiological conditions of the plant did not affect the regualarity of the meiosis. Only temperature exhibited an intimate relationship with the unstability.

(9) The meiosis of the pollen mother cells of different strains of balsam plant were not similarly affected by the equal degree of temperature. The maximum day temperature of 35° C. affected Strain 1, very strongly, and it affected Strain 3, rather markedly, while it gave no effect to Strain 2.

(10) High temperature seems to affect the protoplasm of the pollen mother cells to change its viscosity. Such abnormal change of viscosity may be associated with the unbalance of the energies which control the mechanism of meiosis.

(11) Under the climatic condition of Taihoku, there is a high possibility that the susceptible strain of the balsam plant may give rise to euploid or aneuploid progenies, because, the air temperature of Taihoku during the growing season of the balsam plant arises very often above 32° C.. The meiosis of the balsam plant is affected markedly by such temperature giving pollen grains with unusual chromosome number.

(12) From the facts demonstrated above, the author has reached the conclusion that the seasonal high air temperature of the tropical and subtropical regions seems to play an important rôle in the occurrence of chromosomal mutation in some plants such as the balsam.

(13) Short a discription of about three individuals of aberrant type obtained during the course of the experiment are given in Chapt. XI.

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PLATE IV [I]

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PLATE V [II]

PLATE VI [III]

Explanation of Plate VI [III]

(Photomicrographs)

Fig. 22. An anaphase, showing all the unpaired chromosomes, as in Fig. 20, separated at the equator and spreading into the cytoplasm.

Fig. 23. An anaphase, showing all the unpaired chromosomes, as in Fig. 20, separating irregularly along the axis of a giant spindle.

Fig. 24. Side view of the first anaphase, showing the fractured chromosome illustrated in textfig. 49. The arrow indicates the fructured point of chromosome.

Fig. 25. Interkinesis, showing the daughter nucleus illustrated at the right hand side in textfig. 52.

Fig. 26. Polar view of the second equatorial plate with 11 chromosomal units, showing one plate illustrated at the lower side in textfig. 58.

Fig. 27. The second metaphase, showing two chromosomes extrued out of the daughter nuclei.

Fig. 28. Side view of the second metaphase with the lagging chromosomes illustrated in textfig. 62.

Fig. 29. Side view of the second metaphase, showing the chromosomes illustrated in textfig. 63.

Fig. 30. Polar view of the second metaphase, showing the union of both equatorial plates, illustrated in texifig. 64.

Fig. 31. Side view of the second metaphase, showing the precociously splitted chromosomes illustrated in textfig. 66.

Fig. 32. Side view of the second anaphase, showing the random separation of chromosomes.

Fig. 33. Side view of the second anaphase, showing the union of poles of different spindles, illustrated in textfig. 74.

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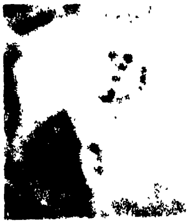
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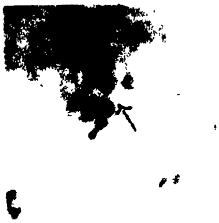
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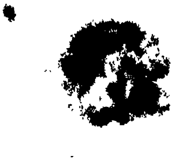
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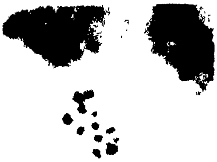
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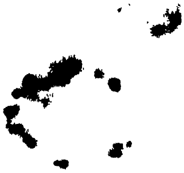
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PLATE VII [IV]

Explanation of Plate VII [IV]

(Photomicrographs)

Fig. 1. Normal form of Strain 1 of the balsam plant.

Fig. 2. Tricotiledonous mutant appeared among the progenies of Strain 1.

Fig. 3. Willow-leaved mutant appeared among the progenies of Strain 1.

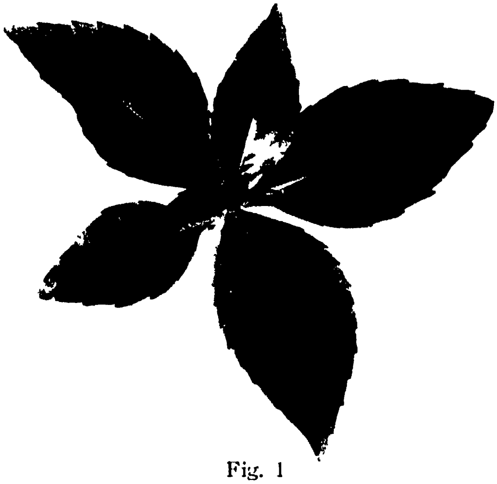

Fig. 1

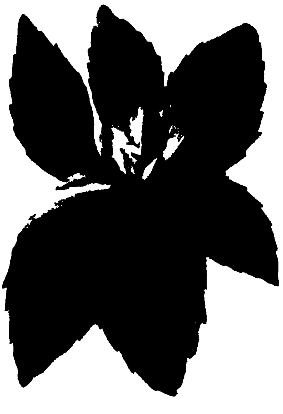

Fig. 2

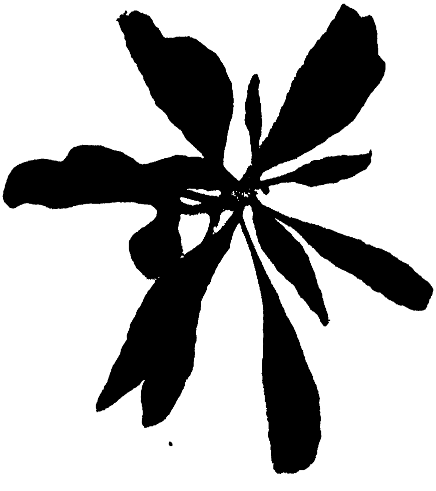

Fig. 3

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